BIOCONVERSION OF ORGANIC WASTE:

THE POTENTIAL FOR RECYCLING DOMESTIC ORGANIC WASTE IN HOBART, TASMANIA

by

Paul Jay

Bachelor of Arts

Submitted in Partial Fulfilment for the Degree of Master of Environmental Studies

Centre for Environmental Studies

Department of Geography and Environmental Studies

University of Tasmania

1997

STATEMENT OF AUTHENTICITY

This thesis contains no materials which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. To the best of my knowledge and belief, this thesis contains no materials previously published or written by another person, except when due references is made in the text of the thesis.

Paul Jay

22 December 1997

ABSTRACT

This study examined the potential for recycling domestic organic waste in Hobart, within the context of the Tasmanian Solid Waste Management Policy (1994), which encompasses both home composting and centralised large scale composting. The effectiveness of the Hobart City Council's home composting program and the viability, for the Council to establish a centralised composting scheme, was examined.

The study analysed the impact of state legislation and policies on waste management in Tasmania and examined the rationale for bioconverting organic waste into compost. The biological aspects of bioconvertion, and the various composting systems, composting technologies and the process control required for large scale composting, were investigated. A survey, to determine the community's current recycling experiences and practices for organic waste and to assess community support for a centralised composting scheme, was carried out in April 1997 in the Hobart municipality.

The study found anomalies, with a significant proportion of the community either excluded from, or not satisfied with, the levels of information in the Council's home composting program. The type of compost bins promoted in the Council's incentive based program were also not found to be conducive for use in all housing types. The study analysed the limitations in the Council's home composting program and proposed a number of approaches for the Hobart City Council to improve its promotional and educational strategies, and incentive based programs.

The study found that there is strong community support for the Council to pursue large scale composting, as an alternative to landfilling organic waste. The majority of households indicated willingness to pay for the cost and ensure logistic support for the recycling scheme. The study identified a number of concerns associated with centralised composting schemes and proposed a number of strategies for the Council to take into consideration when embarking with the recycling scheme. The study concludes by offering areas of future research and the potential to encourage the wider involvement of all councils in waste management issues.

ACKNOWLEDGEMENTS

Specific acknowledgement must be made to my supervisor, Dr Lorne K. Kriwoken, whose inspiring and positive affirmation was vital to the completion of the study. I am grateful for his time, patience, experience and encouragement.

I am grateful to Dr Peter Wilde for introducing me to social survey methods. I thank him for his assistance with developing the methodology and the questionnaire for the survey.

I like to express my gratitude to my friends, Claudia Russmann, Jason Bardbury, Maree Bakker, Catherine Nicholson, Charlene McInnis and Greg Philips, for their assistance with and sustained interest in the study. I would like to warmly thank them for their time, patience, flexibility, friendship, moral support and the interesting discussions, the dinners and red wine.

A special thanks to all the people who participated in the survey.

I also thank all the staff and students at the Centre of Environmental Studies for the contributions they made towards the study and the moral support they gave throughout the duration of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCING THE STUDY

1.1 INTRODUCTION AND BACKGROUND TO THE STUDY

In the past people basically relied on four methods of waste disposal: they either reduced the amounts they generated, dumped or buried it, burnt it, or reused or recycled it (Hubick 1991). These four disposal methods are still the basis for today's waste management systems. However, there have been significant science and technological advancements in how the four disposal methods are carried out. This particularly applies to minimisation of the generation of waste; systematic resource recovery operations, and high technology equipment to collect, sort and convert waste into a recycling resource; high technology large scale incineration plants; and improved landfill designs to prevent pollution escaping into the environment.

It is beyond the scope, nor is it the intention, of this study to explore all the advances made in waste disposal methods. Rather, this study will examine the advances made in the recycling of organic waste. The focus will be to explore the potential of recycling domestic organic waste in Tasmania, with reference to the developments that have taken place with recycling organic waste in the Western industrialised nations.

It is well known that in the past organic waste was recycled to improve the fertility of agricultural soil. For example in the Western world, in the 18th and 19th Centuries, the carts which brought fresh produce to urban areas took the organic waste back to the farm. Farmers composted the organic waste and applied it in their fields or dug it into the soil. The Chinese further advanced their composting systems to compost sewage and used the compost to improve the fertility of their agricultural fields. The reliance on the fertiliser value of organic waste had been so significant that it has been used to warrant prosperity of past civilisations (Hughes 1980).

The Industrial Revolution however brought about a reduction in the use of organic waste to improve soil fertility. The 19th century saw the boom in industries and urban cities. The growth of cities increased pressure for greater food production. Industrial progression resulted in the development of cheap chemical fertilisers (Mathur 1991). As chemical fertilisers had the advantage of being cheap, ready to use and much easier to apply than compost, farmers readily turned to chemical fertilisers.

With chemical fertilisers replacing compost as the soil conditioner, there was no longer a demand for organic waste. Consequently, the disposal of organic waste became an issue. And as cities grew larger, so did the amount of organic waste requiring disposal. Open dumping was the initial disposal method for the waste. The waste which was first dumped on the streets was later collected, hauled and dumped, along with other waste, into open tips, rivers or streams, and latter, into the seas.

These experiences also reflect the waste disposal practices in Tasmania. However, due to the low population and with the availability of land, waste was also dealt with on an individual basis or fed to animals (Clouser 1989). The large backyards served as ideal burial or composting sites for organic waste.

It was the putrescible nature of organic waste which raised public health concerns and placed pressure on authorities to introduce management for the safe disposal of the waste. Over the years, a number of gradual improvements took place in the methods used to dispose organic waste which eventually saw the waste being collected and either burnt in large scale incinerators or buried in landfills. Incineration, as a waste disposal method, was less popular and did not receive much support due to its high maintenance/energy cost and the atmospheric pollution it created. Landfilling, on the other hand, became the more widely practiced disposal method for organic waste.

Once buried, no further consideration was given to the waste. The lack of environmental data and research on the life cycle of waste inside landfills perpetuated the myth that waste decomposed safely into some harmless substance (Rathje 1991).

This 'out of sight, out of mind' approach to dealing with organic waste served its purpose in the past, when the rates of both consumption and waste generation, were low. However, as developed countries prospered after the Second World War, wealth created a climate for increased consumerism (Evans 1994). Products were made to be versatile, cheap and convenient, often designed to be discarded after short use. The population increase in the cities, in turn, resulted in the generation of waste on an unprecedented scale. For example, the European Union is known to produce up to 2 billion tons of solid waste per annum (Hubick 1991), while it is estimated that the US produces 158.9 million tons per annum (US EPA 1990), and in Australia waste generation is estimated at around 12.8 million tons per annum (Hubick 1990).

The developing cities placed demand on land for urban development. As suburbs sprawled and rural land was urbanised, the problem of finding suitable sites for landfills to replace the old tips and dumps, followed.

It is in this climate that the wave of environmental consciousness swept the globe in the 1970s, raising public awareness on environmental issues (Walker 1992; Evans 1994). Public concerns translated into community demand for environmental protection, and resulted in on-going pressure for the reduction of waste and for the conservation of resources (Glover 1995; US EPA 1990). Western governments responded with environment protection legislation (Evans 1994) and introduced stringent environmental standards to regulate waste management. Local communities also began taking measures to protect their own interests (Glover 1995). One example of community action is reflected in the NIMBY (Not In My Back Yard) syndrome, whenever the question of locating landfills arises. Local communities, justifiably, object to the smelly, dirty, and noisy landfill, being sited in their neighbourhood.

Waste disposal authorities are at a 'cross-road' with changing attitudes and the increasing awareness in the management of waste (Hubick 1990; Glover 1995). To pursue the 'out of sight, out of mind' approach to waste disposal is now unacceptable. Finding suitable sites, dealing with community objections and complying with current environmental standards will inevitably raise the cost of waste management. While, on the other hand, communities, who are paying for waste management, reject the notion of landfilling waste and demand for the conservation of resources. Waste management strategies developed for Western industrialised nations, propose the minimisation of waste at the source and improvements in resource recovery operations to reduce the amount of waste entering landfills. The pressure is mounting on waste disposal authorities to seek alternative solutions that satisfy community concerns and comply with environmental legislation.

In Tasmania, as in most Western industrialised nations, domestic putrescible waste makes up almost half the waste stream (Dowson 1991; Clouser 1989). By expanding the definition of organic waste to include other household organic materials such as paper waste, garden waste and sewage sludge, organic waste can account for almost 70 per cent of urban solid waste.

Over the last decade there has been increasing support for organic waste to be diverted from landfills, bioconverted into compost and marketed (Miller 1991). Reducing the large proportion of waste entering the waste stream will offer significant benefits in terms of the issues and cost associated with organic waste management and disposal.

The National Waste Minimisation and Recycling Strategy which proposes a 50 per cent reduction in waste entering landfills by the year 2000, suggests for a 20 per cent reduction in putrescible waste entering landfill by 1995 (CEPA c1992). The Tasmanian Solid Waste Management Policy (TSWMP) (1994) promotes the bioconversion[1] of organic waste into compost as the viable alternative to landfilling (DELM 1994b). Currently very little is known about the rate of recycling domestic organic waste in Tasmania (Maunsell 1995).

The TSWMP (1994), which reflects the National Waste Minimisation and Recycling Strategy, proposes the following two methods to compost domestic organic waste:

- encouraging the promotion of home composting as a means to divert domestic food/organic waste from the waste stream. This strategy has been pursued by most councils in Tasmania with some offering subsidised compost bins as an incentive to encourage householders to compost at home for use in the householder's garden.

---

[1] As the term 'composting' is more widely used in place of bioconversion, it will be used in the rest of this study.

- encouraging the establishment of large scale composting facilities to compost the organic fraction of municipal solid waste. This strategy is proposed within the context of regional waste management centres, centrally located waste disposal facilities jointly managed and operated by a number of municipalities. These would enable a viable large scale composting operation, in terms of the volume of putrescible waste and the application of appropriate technology with best environmental practices, through economies of scale.

1.2 AIM OF THIS STUDY

This study aims to determine the effectiveness of the Hobart City Council's home composting program as a waste diversion strategy and the viability for the Council to establish and operate a centralised large scale composting scheme, to deal with the organic fraction of municipal solid waste.

This will involve the following objectives:

- determine the status of solid waste management in Tasmania;
- analyse the rationale for the bioconversion of organic waste into compost, as the alternative to landfilling;
- identify what is entailed in the bioconversion of organic waste; and
- determine the current recycling experiences and practices, for organic waste, in the Hobart municipality, and, assess community support for a large scale composting scheme.

1.3 OUTLINE OF THIS STUDY

Chapter 2 examines the status of waste management in Tasmania, analysing the changing phase and the future directions of waste management, through a combination of literature review and personal communications with relevant authorities.

Chapter 3 identifies the problems with landfilling organic waste and examines the rationale for converting organic waste into compost. This Chapter reviews current literature to determine the issues associated with landfilling organic waste and examines the arguments for bioconverting and marketing the waste. It will also examine the issues associated with the change from landfilling to the bioconversion of organic waste, as the viable alternative disposal method.

Chapter 4 examines what is entailed in the bioconversion of organic waste. This Chapter is intended as a database on composting. The Chapter consists of a review of the literature on:

- microbiology and the environmental conditions required for the biological transformation of organic matter into compost; and
- various composting systems and current technologies, and the process control required to ensure a successful and viable composting operation, and for the production of a safe and quality compost.

Chapter 5 discusses the methodology for a public survey conducted in the Hobart municipality as part of this study. The purpose of the survey is to determine the organic waste recycling experiences and practices of the Hobart community, and, to determine the levels of community support available for the concept of a Council operated centralised large scale composting scheme, to deal with organic waste.

Chapter 6 presents the results of the survey carried out in the Hobart community. The survey examines the: participation rate [illegible] for current recycling programs for low to moderate biodegradable waste; present disposal practices for domestic organic waste (i.e., kitchen/food waste, green waste and paper waste); the effectiveness of the Hobart City Council's promotional and educational strategies; the effectiveness of the Council's incentive program to encourage households to take up home composting; determine the characteristics of households which carry out home composting; and analyse community support for centralised large scale composting schemes.

Chapter 7 presents the discussion and conclusion of the study. The Chapter analyses the survey results and identifies the limitations of the Hobart City Council's current home composting program. The Council's strategies are reviewed with the aims to improve their home composting program. The Chapter also assesses the viability of the Council operating a large scale composting scheme and discusses a number of factors to ensure the success of the recycling scheme.

1.4 Defining Organic Waste

Most people generally associate the word 'organic waste' with something readily degradable. The term "organic" is however defined in the Concise Oxford Dictionary as "having ... organised physical structure of plants or animals", or "existing as constituent of organised bodies or formed from bodies so existing, containing carbon in its molecule" (Fowler and Fowler 19[illegible]4).

The former definition reflects the widely held perception for organic waste, that is, given the appropriate conditions, it has the potential to decompose quickly. By the later definition however, with the notable exception of glass and metal, almost all materials in municipal solid waste could be included as organic waste.

For the purpose of this study, an attempt will be made to narrow the definition of organic waste. Some organic materials have been identified to decompose easily and quickly to produce the byproduct, compost. These include materials such as food scraps, paper products, sewage sludge and garden waste. Since this study is concerned with recycling domestic organic waste, the definition of organic waste will be restricted to:

- left over kitchen/food waste (i.e., food scraps, meat and bone scraps, eggs shells, coffee grounds and tea leaves);
- paper waste which includes newspaper, white paper, paper packaging and cardboard boxes and magazines; and
- garden waste (i.e., grass clippings, weeds, raked leaves, branches from plant or tree clippings; and general garden waste such as broken fences and shovels handles).

2. Waste Management in Tasmania

2.1 Background

Under the *Local Government Act 1962*, councils in Tasmania have the primary responsibility to deal with all waste generated within their municipality. The Act gives councils the power to acquire land and designate waste disposal sites as required. Councils usually own their own disposal sites and thus have management, budgetary and environmental controls for the whole operation (Glover 1995).

As in most parts of the Western world, traditional waste disposal methods were used to deal with waste. Solid waste were collected, hauled and buried in landfills, then commonly known as 'tips' or 'dumps'. The disposal sites were generally trenches, gullies, and specially designed holes on degraded land or in some instances land surrounded by mounds (Glover 1995). Sewage waste on the other hand, was released into rivers and seas (Leonard 1993).

With scant laws to protect the environment, in the past environmental safeguards in waste management were minimal. Earlier legislation used to regulate waste management were the *Public Health Act 1962, Environment Protection Act 1973* and associated Regulations, and the *Groundwater Act 1985.* As a requirement of these Acts refuse in disposal sites had to be regularly covered with soil and the ignition of refuse or the landfilling of hazardous waste were strictly prohibited. In some instances leachate had to be trapped and treated. However, it was found that in most instances waste management practices were lax and disposal sites were often poorly sited and operated (DEP 1992; Glover 1995). The disposal sites were frequently open for public use, and refuse ignited to hasten degradation, minimise vermin attraction and conserve space. Sites were also found to be established on natural drainage lines, contaminating ground and surface waters. In other cases, disposal sites have been located in areas where there is a lack of accessible cover materials and some tip faces were difficult to cover due to their size.

These poor waste management practices did not cause a great deal of public concern in the past. Factors such as ignorance, lack of environmental data and background information, and the lack of political will to protect the environment (Davis 1985) helped to sustain the myth that disposed waste decomposes into some harmless substance (Rathje 1991). The small dispersed population of Tasmania also meant that waste generation was concentrated in only a small number of areas (Leonard 1993). This, in conjunction with the usually short life spans of the old 'tips or dumps' (Glover 1995), has prevented serious environmental degradation on a large scale from occurring or being recognised by the community. Sewage waste discharged into waterways would not have raised serious public concern, as the small size of the island state would have meant the discharged effluent would have been carried away fairly quickly into the seas (Leonard 1993).

Between the 1970s and the 1990s, a number of changes took place in waste management. Earlier changes focused mainly on improving the collection and disposal infrastructure. This lead to the mechanisation of waste collection, with the introduction of garbage bags, smaller garbage bins and large compaction vehicles, resulting in a much quieter and cleaner waste collection service (Glover 1995). Measures were also introduced to improve practices at waste disposal sites. However, as most established disposal sites have inherent problems such as poor siting, they continued to pose a risk to the environment. The late 1980s saw a shift in focus from landfilling of waste to resource conservation measures. National waste management strategies were integrated into local waste management plans, and by 1994, Tasmania had in place its first solid waste management policy. This provided further impetus for the transformation to more environmentally friendly waste management systems in Tasmania.

2.2 THE STIMULI FOR CHANGE IN WASTE MANAGEMENT

Three factors have been largely associated with the changes in waste management (Glover 1995): public opinion, economic influences and government regulations.

2.2.1 PUBLIC OPINION

Tasmanians have an affiliation with the environment. Since the 1960s, Tasmanians have been exposed to a number of local environmental issues and disputes. The more dramatic disputes captured national headlines, raised public concern for the environment and saw the rise of the environmental movement in the state and nationally. Nonetheless, it was often the less prominent issues, such as pollution and toxic waste disposal that brought home the reality of environmental issues on a more personal level.

Concern over the problems caused by waste disposal is reflected in the community's entry into the waste management debate. The community is now better placed to protect its own interest (i.e., the impact on property value or local amenity) and is no longer content with the unsightly, smelly, dusty and noisy waste disposal practices of the past. For instance, the Clarence community forced for an early closure of its Lauderdale tip, on the basis that the disposal site was polluting the environment (Bakker pers. comm 1997). Community objection to landfilling of waste is also displayed by strong protest whenever the question of siting new landfills is raised.

The degradation of the environment not only had an influence in shaping public opinion to demand protection for the environment but also motivated the public to do something positive for the environment. The word 'waste' took on an emotional tone with calls for resource conservation strategies. Landfilling came to be seen as a waste of resources. In wanting a sustainable solution, the community backed the idea of "Reduce, Reuse and Recycle" when it was initially canvassed as the potential resource conservation and waste minimisation strategy. This was later reflected in the high participation rate when councils began operating recycling programs (DELM 1993).

2.2.2 ECONOMIC INFLUENCES

The cost of waste disposal in Tasmania is relatively low compared with the rest of Australia. A survey carried out in 1990 found that the cost of collection and disposal of waste in Tasmania is about $15 per person per annum, while the national average is around $28 per person (Auditor-General 1993). One reason for the low waste disposal cost is the relatively low cost of land in Tasmania. However, two other factors that keep the cost of waste disposal artificially low in Tasmania are also recognised. One is the low priority given to waste disposal in the state, reflected in councils' inadequate management of disposal sites and non-compliance with license conditions (DELM 1994b). The other is an artifact of accounting whereby councils tend to state only the operational and some ongoing capital cost but exclude much of the indirect cost such as interest on loans for waste disposal sites, administration, supervision, indirect overheads and the rehabilitation of disposal sites (Auditor-General 1993; Maunsell 1995). Shortfalls are made up by using funds from other sources. It is possible for councils to cross-subsidise, as municipal rates in Tasmania are based on the total cost per year of providing all their services to the community (Auditor-General 1993).

To carry out the objectives established in the state environment protection legislation and the TSWMP (1994) in waste management practices, councils now need to re-evaluate their waste disposal costs. Most established disposal sites in Tasmania do not conform to the required standards, and up to 50 per cent are expected to reach the end of their lives within 5-10 years (DELM 1993). Councils are therefore left with the choice of either upgrading their present sites or establishing new ones (DELM 1994b; Glover 1995). Either of these options place councils in a position where they have to face up to the enormous cost involved in upgrading old sites or establishing new sites in accordance with the required standards.

The transportation of waste from urban areas to rural or distant landfills is another factor which councils now have to consider in their waste disposal costing. With suitable disposal sites becoming scarce, councils face the prospect of locating future disposal sites out of urban areas, and in some instances outside of their respective municipalities. Transferring waste from urban areas to distant or rural sites will require new infrastructure, such as transfer stations and extra fleet of vehicles, which will inevitably raise the cost further.

2.2.3 *State Government Legislation*

Tasmania enacted its *Environment Protection Act* in 1973 and established the Department of Environment[1] as the statutory authority to implement the Act. The Department of Environment carried out a survey of all waste disposal sites in the state in 1974 and found, of the 110 sites[2] in operation, many were poorly managed and severely impacting the environment (DEP 1992). To rectify the situation, a number of measures were introduced through the *Environment Protection (Waste Disposal) Regulation 1974.* This contained measures to deal with the siting of new landfills, prevent the contamination of ground waters, improve practices at disposal sites and dealings with hazardous waste. Councils were bound to abide by these measures as a requirement of their waste disposal site licensing conditions.

Throughout the 1970s and 1980s, the Department of Environment monitored waste management practices and assisted councils with information on site selection and the operation and management of disposal sites. In this role, the Department identified issues and worked on developing strategies that offered long term solutions. These strategies are formalised in the TSWMP 1994, discussed in Chapter 2.2.3.1.

At about the same time as the TSWMP (1994) was being developed, the state government reviewed its environment and planning legislation and developed an integrated package of new legislation, which was to become the Resource Management and Planning System (DELM 1994). Central to the new Resource Management and Planning System is the concept of sustainable development. The new legislation includes the *States Policies and Projects Act 1993* (SPPA), the *Environmental Management and Pollution Control Act 1994* (EMPCA), which replaced the old EPA 1973 as Tasmania's key environmental legislation, and the *Land Use and Planning Approval Act 1993* (LUPAA). These Acts provided an opportunity for the objectives of the TSWMP (1994) to be enforced by law. The impact of the legislation on waste disposal is discussed in Chapter 2.2.3.2.

---

[1] The Department of Environment was renamed to the Department of Environment and Planning, and later, to the Department of Environment and Land Management (DELM), by which it is still currently known.

[2] At present there are 60 disposal sites in Tasmania

2.2.3.1 TASMANIAN SOLID WASTE MANAGEMENT POLICY (1994)

The Tasmanian Solid Waste Management Policy (1994) aims to achieve two goals. They are firstly, to promote waste minimisation and resource recovery and secondly, to protect the environment from effects arising from landfills (DELM 1994b). The principal strategies to achieve the goals of the TSWMP (1994) are in effect those promoted for waste management systems, (discussed in Chapter 3.2) including waste minimisation; recycling and re-use; energy recovery; safe & secure disposal; and the rehabilitation & future use of disposal sites. The TSWMP (1994) establishes a number of guidelines to achieve these goals. The main guidelines are discussed below.

Overall, the TSWMP (1994) mirrors the National Waste Minimisation and Recycling Strategy (1992) developed by the Commonwealth Environment Protection Agency (CEPA). An important aspect of CEPA's strategy is the setting of a national target to half the 1991 level of waste entering landfills by the year 2000 (CEPA c1992). This target is adopted in the TSWMP (1994) (DELM 1994b). The time frames to attain the state targets is: for 15 per cent reduction in 1993; 25 per cent reduction in 1995; and 50 per cent reduction by the year 2000 (DELM 1994b).

In addition to the overall waste reduction target, the TSWMP (1994) establishes interim performance targets for each type of recyclable material recovered which are to be reviewed in light of progress towards achieving the overall 50 per cent reduction. See Appendix 4 for performance targets for recycling in Tasmania.

Although a review of the state target for waste entering landfills and the performance targets for recycling materials were to have been carried out in 1995, there was no current information available on meeting these targets in 1997 (Bakker pers. comm. 1997).

The TSWMP (1994) recognises the high proportion of organic waste entering the waste stream and advocates its reduction. However, unlike the target set by the National Waste Minimisation and Recycling Strategy (CEPA c1992) which aims for a 20 per cent reduction in organic waste, the TSWMP (1994)'s target for organic waste reduction is incorporated into the overall 50 per cent reduction. The TSWMP (1994)'s organic waste reduction strategies includes the chipping/shredding of green waste, the promotion of on-site composting (i.e., home composting) and canvases the potential of centralised large scale composting.

An important aspect of the TSWMP (1994) is its promotion of the user pays principle. The cost of waste disposal in Tasmania has been subsidised by the community through the flat-rate system of municipal charges (DELM 1994b). To protect the community from subsidising the true cost of waste disposal, the TSWMP (1994) advocates that the old existing license fee be replaced with a system of waste disposal fees, calculated by weight of material going to landfill. Although this fee is designed to discourage landfilling and encourage councils to explore alternative uses for waste, it is currently shelved as a result of extensive lobbying from councils (Bakker pers. comm. 1997). However tip fees are advocated by the TSWMP (1994) for individuals who dump waste at the disposal site. The idea of the fee is to discourage the dumping of waste and encourage recycling.

The TSWMP (1994) also promotes a rationalisation in the number of disposal sites in the state and encourages the establishment of regional waste management centres. It advocates that the number of disposal sites be reduced (presently 60) to three regional waste management centres. The regional waste management centres offers the opportunity for councils to co-operate and share waste disposal facilities. The sharing of disposal facilities would allow for councils to share the cost of applying appropriate technology and provide the required level of services now established for waste management.

2.2.3.2 The Impact of Government Legislation on Waste Disposal

The State Policy and Projects Act 1993 includes provision for the establishment of state policies by the Sustainable Development Advisory Committee. The TSWMP (1994) was prepared as a fore runner to it becoming a state policy under the Act. At the time of writing, the TSWMP (1994) had not become a state policy. Councils, although carry out the decision making in waste management, are required to ensure that operational decisions pursue the objectives of the TSWMP (1994) DELM 1994b; Haynes 1996).

The *Environmental Management and Pollution Control Act (1994)*, establishes the statutory power of the Department of Environment and Land Management (DELM) to ensure that the minimum environmental standards are met in waste management practices. Councils are no longer permitted to continue operating disposal sites that are known to cause environmental harm [Clause 2C of EMPCA 1994]. Those with existing poorly managed disposal sites are required to upgrade and improve their waste management practices. As an enforceable measure, councils can be required to specify environmental improvement programs, which outline the objectives they propose to achieve and the time frame in which they will achieve those objectives [Clause 38 (1) of EMPCA 1994]. The DELM has the obligation to monitor these environmental improvement programs [Clause 28(4) of EMPCA 1994] and penalise councils which fail to comply with the required operating standards [Clause 67 (1) of EMPCA 1994].

The *Land Use Planning* and *Approval Act 1993* (LUPAA) establishes a system of planning instruments to set objectives, policies and controls for the use, development and the protection of land. LUPAA 1993 [Clause 51(2)] requires councils to obtain permits prior to establishing waste disposal sites. Permits for all new disposal sites are issued on the basis of the nature of waste to be accepted at the disposal site and the proposed level of activity. Levels of activity for disposal sites are established in the site classification system, which is the major component of the TSWMP (1994)'s safe and secure disposal strategy.

2.3 Transformations in Waste Management

Of the transformations that have taken place in waste management, the three main notable changes are the changing role of councils, improvements of environmental standards in disposal sites and the development of infrastructure for waste minimisation and resource conservation strategies. These are discussed below.

2.3.1 The Changing Role of Councils

In the past councils had a total monopoly over waste disposal operations. Years of experience with waste management have allowed them the opportunity to study the disposal habits and needs of households and industry in their municipality, as well as develop expertise in the various aspects of waste disposal practices. This puts them in a position of possessing a depth of understanding of local waste management needs.

The progress made in waste management requires a much wider and more specialised range of skills to carry out the entire waste disposal operation. This includes expertise in the area of waste minimisation, environmental management and resource recovery. Councils have had to recognise that their range of expertise falls short of the level of services now required in waste management. Further, they have had to acknowledge that the level of services needed exceeds the capacity of most councils to provide on their own (DELM 1994b; Glover 1995). The task now requires co-operative action of several different specialist parties. These include: environmental experts; producers of waste from both industry and the broader community; garbage collectors; salvaging contractors; operators of resource recovery functions; commodity traders for reclaimed materials; and composting operators.

The specialised parties in most instances are recent entrants into waste management, although in some cases they had existed in the traditional system in a much reduced capacity. Their lack of experience in the area of waste management puts them in a position where they would require support to establish their operations (Glover 1995). This meant that councils not only have had to enter into a partnership with the parties, but also have had to take on the task of assisting the parties in carrying out their operations. In most cases this involved establishing new infrastructure for the parties to carry out their specialised role.

The sharing of responsibility in effect changed the role of the councils from that of being the sole provider of the service, to becoming a team player in waste management (Glover 1995). Their responsibilities and obligations still require them to assure proper disposal of waste, as well as to ensure that public health and the interest of their ratepayers are not compromised. This puts councils in a position where the challenge for them is to work cooperatively with the specialised parties but at the same time remain the key player in waste management, by overseeing the whole waste disposal operation in order to ensure its success.

2.3.2 Improvements in Environmental Standards of Disposal Sites

The initial environmental improvements in disposal sites followed the introduction of the *Environment Protection Act 1973* and *Environment Protection (Waste Disposal) Regulations 1974*. The improvements were achieved through restrictions on the siting of new disposal sites, and improvements in waste disposal practices, such as the prohibition of fires at disposal sites and conditions to deal with hazardous waste.

Councils were also required to take measures to prevent leachate contaminating surface and ground waters.

The progression made in waste management created a climate for the implementation of environmental standards in landfills and landfill management practices. A major advancement was made through the TSWMP (1994)'s site classification system, which establish minimum levels of management and operating standards for waste transfer stations and landfills. The measures introduced through the system saw councils introducing:

- recycling depots for recyclable materials at waste transfer stations and disposal sites. This encourages the community to leave their recyclable materials at the depot rather than dump it as waste.
- chippers/shredders to recycle green waste into mulch. Chipping or shredding green waste into mulch for use in parks and gardens prevents green waste entering landfills and saves landfill space.
- leachate collection and treatment. Treatment of leachate is presently carried out on site and at sewage treatment plants.
- methane gas collection facilities. Four councils in Tasmania (Glenorchy, Hobart, Launceston and Devonport) have carried out tests to establish the viability of extracting methane from landfills. Presently, only Hobart City Council has established methane collection facilities. A disincentive for councils to invest in methane collection facilities is their inability to compete for markets with the state's cheap hydropower.

2.3.3 The Development of Infrastructure for Waste Minimisation and Resource Conservation Strategies

2.3.3.1 Waste Minimisation Programs

The waste minimisation strategies have been largely aimed at industry with an emphasis on reducing the amount of packaging entering landfills. Packaging includes glass, paper, steel, plastic containers and bags, liquid paperboard cartons, and aluminium cans. The product design can reduce the amount of packaging discarded and industry is encouraged to minimise waste by reducing the volume and weight of packaging.

Industry has developed an environmental code of practice to regulate packaging design to achieve the strategy's objectives (DELM 1994b).

2.3.3.2 Resource Recovery Programs

The Department of Environment began encouraging councils to recycle as early as 1976 (DEP 1992). A study conducted in 1987 found that a number of recycling programs to recover materials, such as glass bottles, paper, steel and aluminium cans, was operating throughout the state (Balmer 1988). However, the study also discovered that the programs were sporadic and on a small scale. The early resource recoverers were generally multi-activity industries that tended to conduct recycling activities as one part of their overall operations. Most were also found to operate on a casual/part time basis, usually when the prices for the recyclable materials were high. A very small number which focused exclusively on recycling was made up of community based organisations[3] that generally offered their services for free.

By the 1990s, however, a more professional approach to resource recovery emerged, with councils formalising their recycling programs. Many of the recycling programs were contracted out to private contractors who in most instances carried out the other aspects of resource recovery functions[4] as well. A state wide study carried out by the DELM in 1993, found that 76 per cent of councils operated drop-off depots for recyclables, 63 per cent operated community based recycling facilities (e.g. Scouts and St. Vincent de Paul), while 28 per cent[5] undertook kerbside recycling collection services. Materials collected via the kerbside collection include aluminium cans, glass bottles and jars, PET and HDPE plastic, and milk and juice cartons. The recycling depots receive all the materials mentioned in kerbside collection as well as other recyclables such as lead batteries, clothes/rags, metals, cardboard, tin, newspaper and timber and building materials.

[3] Firms which offer employment for disabled people or people employed under the Commonwealth Employment programs.

[4] Resource recovery functions include sorting, processing and delivery to commodity traders or to industry.

[5] Though there have been no surveys conducted to determine the present number of councils operating kerbside service, this figure is expected to be much higher.

2.3.3.3 RE-USE (SALVAGING OPERATIONS)

Salvaging rights were granted to private contractors to remove re-useable materials from the tip face. Presently three councils in Tasmania have salvaging operations at their disposal sites. These include the Deloraine City Council, Hobart City Council and the Glenorchy City Council. A spokesperson for Resource Co-operative, a salvaging contractor for the two main disposal sites in Southern Tasmania, indicated that a large amount of materials disposed by households as waste are still in their useable form or suitable for alternative use (Dare pers. comm. 1996). Materials salvaged include clothes, non-ferrous, and ferrous metals, glass, batteries, whitegoods, plumbing fixtures, building materials, carpet, furniture, automotive parts and toys. The salvaged materials collected are resold to the public as second hand goods.

2.3.3.4 ORGANIC WASTE RECYCLING

Councils currently carry out a small number of organic wastes recycling programs. Chipping and mulching of green waste is one program that is carried out by most councils. Residents are required to drop of f their green waste at chipping and mulching centres (recycling depot), which are usually located at the disposal site or transfer station. The recycled green waste, though in some instances sold to the public, is mostly used by council in parks and garden maintenance. Composting of sewage sludge is another organic waste recycling program in operation, although currently it is only carried out by two councils. One of these, which is located in Ulverstone, uses the windrow composting method to compost the treated sludge from treatment plants, while the other, Hobart City Council, uses the vermicomposting technique to compost its sludge. In both these programs, the compost, although also sold to the public, is mostly used in the council's own parks and garden maintenance operations.

In addition to the above programs, most councils have a home composting program in place to encourage households to deal with organic waste on site. The home composting program is an important strategy as it deals with household putrescible waste which makes up almost 42 per cent the domestic waste stream (Clouser 1989; Dowson 1991) Educational material with regards to home composting and subsidised compost bins are presently used to encourage households to compost at home.

2.4 CHAPTER SUMMARY

Waste management in Tasmania mirrors the experiences of other Western industrialised countries. Community concern and government legislation has been the key factors for the shift from the environmentally degrading disposal methods of the past to a more environmentally friendly waste disposal system. The community who pays the waste disposal cost is no longer content with the old waste disposal methods and strongly supports the concept of resource conservation. With up to half of Tasmania's landfills approaching their capacity within 5-10 years (DELM 1993), councils are posed with the problem of replacing them. The community demands and the government regulations, which make establishing and operating disposal sites increasingly difficult and costly, means that it will be beyond the capacity of each council to provide for the extensive level of service now needed in waste management.

The new stakeholders in waste management brought in the much needed expertise to carry out the different aspects of services now required for waste management. The sharing of expertise precipitated the improvements of environmental standards in waste management and the implementation of waste minimisation and resource recovery programs. The pursuit to reduce waste through increased recycling and reuse began with councils formalising their resource recovery programs.

This Chapter examined the impact public pressure, economic factors and environment protection measures, had, in the changing role of waste disposal authorities and the progress that has taken place in waste management in Tasmania. This fulfils the objective to determine the current status of waste management in the state. The following Chapter will analyse the problems with landfilling as a disposal method, and examine the potential for composting the organic fraction of municipal solid waste, as an alternative to landfilling.

3. RATIONALE FOR RECYCLING ORGANIC WASTE

3.1 INTRODUCTION

In the past waste was frequently considered to be an inevitable by-product in need of disposal. Later, the perception gained favour that, once disposed of, wastes materials will decompose into innocuous substances (Rathje 1991; Evans 1994). However, the latter view is increasingly being rejected as more scientific information comes to the fore, indicating that the environment does not have the capacity to act as an eternal waste sink (Pearce *et al.* 1989). Some authors have argued that the release of waste into the environment above the natural assimilation capacity will result in ecosystem malfunctions and manifest themselves as environmental issues, i.e. nuisance odours, ground and surface water contamination (Pearce *et al.* 1989; Walker 1992).

In addition to environmental concerns, the increasing difficulty of, and the rising costs associated with waste disposal, are of immediate concern to waste disposal authorities. Growing community concern about environmental problems caused by waste disposal has contributed to the emergence of community protest action groups, such as the "Not in My Backyard" syndrome (Glover 1995). There is now strong community opposition against the siting of landfills close to residential areas. Public opinion, which can stimulate changes to government attitudes, brought about the introduction of stringent environmental regulations, with the result that modern landfills incorporate safeguards to minimise environmental problems. Therefore, the establishment of new landfills has become more expensive and technically difficult. Furthermore, due to the expansion of urban settlements, landfill space within economically acceptable transport distance is becoming an increasingly scarce resource. As landfills reach the end of their lifespan, waste disposal authorities may have to resort to transporting urban waste to rural or distant landfills for disposal. These factors lead to the rising cost of waste disposal and to the community's objections to paying for poor disposal practices. The changing circumstances and high disposal costs prompt questioning the logic behind the continuing use of landfills.

Governments, particularly in the Western industrialised world, have responded with plans that aim to reduce levels of waste entering landfills through increased recycling of domestic waste. In the US and Australia, national strategies aim at a 50 per cent reduction, while the reduction goal of the different countries of the European Union varies from 50 to 90 per cent (Poulsen *et al.* 1995). Waste management systems, which establish a hierarchy of strategies, have been established in order to reduce the amount of waste and its impact on the environment. While the long-term effectiveness of the waste management systems is still unproven, the measures have to date resulted in the diversion of a small proportion of dry waste from landfills. Meanwhile, the major proportion of municipal solid wastes, which includes the organic fraction, is still being landfilled. Landfilling is a hazardous method of disposing organic waste, as there is a recognised risk of pollution generated by landfill emissions. Although landfill design generally incorporates measures to contain and treat emissions, their effectiveness in pollution prevention is doubtful.

Organic waste is of limited value in its original form. Its putrescible nature makes it a potential health hazard, requiring immediate disposal. However, the organic constituents can be converted into compost within in a reasonable period of time. Compost has a proven value as a plant growing medium (discussed in Chapter 3.4). The potential demand for compost as a soil additive is expected to exceed the present production (Buhr *et al.* 1993). Studies conducted in the US indicate that there will be an increased demand from industries involved in agriculture, silviculture, sod production, residential retail nurseries and landscaping (Gouin 1991; LaGasse 1992; Buhr *et al.* 1993). This demand will be influenced by:

- the depletion of topsoil from actively producing agricultural grounds and in the horticulture sector (fruits, vegetables, ornamental plants);
- the growing demand for potting mix in nurseries and the greenhouse industry;
- the need of organic matter in soils for landscaping and garden maintenance;

- the recognition that compost could replace chemical compounds as a natural pesticide, (i.e. sterilising effect); and
- road construction and urban development.

Currently, commercially available compost is mostly made from peat moss, shredded hardwood bark and milled bark (Gouin 1991). Disadvantages of using these products are the transport costs involved in obtaining them, moreover it is well-known that the harvesting of peat moss is responsible for environmental degradation. On the other hand, a continuous supply of organic waste is theoretically readily available locally and at a low cost.

This presents an incentive for waste disposal authorities to examine the feasibility of composting the organic fraction of municipal solid waste. It is the intention of the following sections to demonstrate that such a move would not only have the potential to substantially reduce the amount of waste entering landfills but also be of significant benefit in economic terms.

3.2 WASTE MANAGEMENT SYSTEMS

The aim of waste management systems is to establish guidelines for the proper management of waste. The establishment of a waste management hierarchy has been an integral part of the management system which has been accepted and approved by most waste disposal authorities, environment protection authorities, environmental groups and Western governments (Society of Environmental Toxicology and Chemistry 1991; US EPA 1993; DELM 1994b). The proposed waste management strategies are, in order of preference: (1) waste minimisation or reduction; (2) resource recovery, (i.e., through recycling or reuse); (3) waste to energy; (4) as a last resort, the safe and secure burial of wastes.

Waste minimisation, the preferred strategy, has the aim of preventing waste generation at the source. This strategy is aimed to a large extent at industry where waste is generated at all levels of production, (i.e., from the raw material stage to the manufacture and the final packaging of the end product). The strategy encourages the waste generator to employ the principle of waste avoidance.

However, the remaining waste stream (post-consumer waste) needs to be dealt with. While some of the waste may be suited for recycling or reuse, other materials will inevitably need to be disposed of. These aspects of the waste management system are largely in the hands of waste disposal authorities that deal with the collection, processing and the final disposal of waste.

Resource recovery is supported by the principle of resource conservation. It aims to divert post-consumer waste materials from the waste stream, thereby creating an alternative supply of raw materials for production. Recovery programs include recycling, reuse and composting. Resource recovery also includes alternative uses of wastes, such as the waste-to-energy or methane production schemes.

The principle of safe and secure disposal is to ensure that the final release of waste has a minimum impact on the environment. In order to achieve this, landfill design must incorporate measures to prevent the escape of landfill emissions. This includes the safe siting of landfills as well as facilities to trap and treat landfill emissions (US EPA 1993; DELM 1994b; Glover 1995). Within the range of improved environmental practices for the safe and secure disposal falls the pretreatment of waste before landfilling. The aim of pretreatment is to stabilise wastes of a putrescible or reactive nature. Suggested methods of pretreatment include bailing, sorting, mixing, shredding and pulverising (National Center for Resource Recovery 1974; Glover 1995).

In recent years, waste disposal authorities have begun to implement the principles of the waste management system outlined above into local waste management practices. As a result, the operation of resource recovery programs and improved environmental standards in landfill design and management have become common practice for municipalities in many parts of the Western industrialised world.

3.3 THE WASTE DISPOSAL ISSUE

Theoretically, the establishment of the waste management system should ensure that a large proportion of the waste material is diverted away from landfills to recycling facilities. However, in reality this does not appear to be the case.

Technically most wastes are recyclable. Economically, however, resource recovery programs can only be viably operated if there are uses and markets for the recovered materials. The combined cost of collecting, sorting, transporting, cleaning and reformulating waste reduces its appeal as a resource. Factors such as reliability of supply, quality, quantity and price are known to affect the ability of recycled materials to compete with virgin resources (Glover 1995). This in turn restricts the types of materials selected for recovery to those with readily available markets. At present, the materials targeted for recovery are dry waste (low to moderate biodegradability), such as metals, glass, plastic and paper.

Waste compositional studies have established that the organic fraction (moderate to high biodegradability) makes up a significant proportion of municipal solid waste. Green and domestic putrescible wastes alone constitute almost 50 per cent of the total amount of municipal solid waste (Glauser *et al.* 1978; US EPA 1990; Cringer *et al.* 1995; Glover 1995). The organic fraction of municipal solid waste is even larger when other organic waste, such as paper waste[1], sewage sludge and other improperly managed organic waste, is taken into consideration. At present, organic waste is of no economic value in its original form (Glover 1995) and hence is not earmarked for recovery[2]. Whilst it is recognised that composting of organic wastes offers the potential to significantly reduce the amount of waste entering landfills, most municipalities continue to landfill these materials, although in recent years, some municipalities have begun to convert organic waste into compost. However, this approach is the exception rather than the rule and the major proportion of municipal solid waste (organic waste) continues to be landfilled.

3.3.1 THE NATURE OF LANDFILL EMISSIONS

Recent field studies have established that the decomposition of organic waste in landfill can result in the emissions of biogases and leachate (Rathje 1989; Finnveden 1992). The types of biogas emitted from landfills include methane, carbon dioxide and traces of hydrogen (Warmer Factsheet 1991). Methane and carbon dioxide are known

[1] Newspapers and white paper are generally recycled, however due to the unstable market for newspapers and poor collection points for white paper a significant proportion of both types of paper still end-up in landfills.

[2] Some states in the US and European Union have began taking measures to bioconvert the organic waste into compost.

greenhouse gases that are linked to global warming, while methane has also been linked to ozone depletion. Issues relating to methane escaping from landfills include explosions and ignition of fires in landfills, foul odours and the gas entering homes through foundations (Warmer Factsheet 1991; WMAA 1994; Poulsen *et al.* 1995)

Leachate is water (such as that from rainfall) that becomes highly contaminated with suspended and soluble materials as it percolates through decomposing waste in landfills (Sobsey 1978). Its escape from landfill sites can contaminate ground and surface waters (National Center for Resource Recovery 1974; Senior and Shibani 1990). Groundwater contamination occurs as a result of leachate percolating through the soil into the watertable. Contamination of ground water is of increasing concern as the drinking water supply of many cities relies on ground water. Surface waters are contaminated either when leachate enters directly into rivers or streams or when contaminated groundwaters reach a point of surface discharge (i.e., rivers, lakes or coastal waters). The contamination of surface waters with leachate can lead to toxic effects on aquatic life (Plotkin and Ram 1984 cited in Senior and Shibani 1990; Rajan *et al.* 1994) or pose a health risk for humans. For example, recreational users of waterways stand the risk of directly ingesting contaminated water (British Medical Assoc. Guide 1989).

Both biogases and leachate have been identified to carry less well known contaminants, such as chloroflurocarbons from dumped fridges and air-conditioners (Finnveden 1992). Potentially harmful chemicals such as pesticides, aliphatic, acyclic, terpenes and aromatics, as well as heavy metals and metals have also been found in leachate (Brown and Donnelly 1988; Senior and Shibani 1990; Rugge *et al.* 1995). Apart from chemical constituents, leachate may also transmit enteric pathogenic micro-organisms. For example, bacteria, viruses, protozoa and helminth as well as two types of polioviruses (types 1 and 3) have been detected in leachate. (Sobsey 1978; British Medical Assoc. Guide 1989). The ability of enteroviruses and bacteria to survive in leachate contaminated waters, is a serious concern as it is now recognised that long term consequences of consuming water infected with low levels of the water borne micro-organisms, can result in the exposure to infectious diseases (Haas *et al.* 1993).

3.3.2 THE CAPACITY OF MODERN LANDFILLS TO MANAGE EMISSIONS

The waste management system requires the final release of waste into the environment to be carried out in a safe and secure manner. Due to the increasing availability of scientific information with regard to the design and the siting of landfills, the establishment and operation of environmentally safe landfills has become an achievable goal (Rathje 1989; Glover 1995). A major technological achievement in landfill design is the development of landfill covers and liners to prevent pollutants escaping from the sites. Landfill covers are designed to trap biogases inside the landfill whereas liners are designed to prevent leachate from leaving the site. Both covers and liners enclose landfills, thereby effectively creating a 'bioreactor'. The concept is based on the ultimate aim of extracting, processing or treating of the trapped substances.

There are a number of arguments, which can be used in favour of the concept of containing landfill emissions. Firstly, since methane is recognised for its fuel value, the idea of trapping the biogas is an economically appealing one. In the US, methane produced from landfills generates approximately 73 billion cubic feet of fuel per year (Rathje 1991). Secondly, it provides a solution to the problem of leachate contamination of ground and surface waters.

Although the concept of the landfill 'bioreactor' is a significant advance from the old concept of dumping sites, there are a number of management difficulties that need to be resolved. For instance, there are several practical factors that restrict the viable harnessing of methane from landfills (Barlaz *et al.* 1990). Methane production is largely determined by the nature of the materials and the decomposing conditions inside the landfill. Since these factors are difficult to control, an accurate prediction of the biogas generation rate at each individual landfill is often not possible. Studies have shown that biogas generation has frequently been found to be much lower than was expected (i.e., between 1-50 per cent of the expected rate) (Barlaz *et al.* 1990; Rathje 1991). As a further complication, landfill covers have a variable ability to contain biogases. There is presently no accurate method of determining the rate at which biogases escape through landfill covers (Barlaz *et al.* 1990). In addition to these issues, markets for the recovered biogas must be found and developed. For example, the Hobart City Council in Tasmania was reportedly unable to sell the methane produced from its McRobies Gully tip site due to the cost not being competitive with the cheaper power provided by the state's Hydro Electric Commission (Chew Liew pers. comm. 1996).

A major disadvantage is the cost involved in enclosing landfills with adequate clay and/or geosynthetic membrane liners and covers. Clay liners are cheaper than geosynthetic membranes, which are beyond the financial abilities of the majority of smaller disposal authorities. The low-cost clay liners, on the other hand, are difficult to install and have been found to be less reliable than geosynthetic membranes (Daniel 1995).

In addition to the cost of liners, authorities will have to finance the establishment and/or on-going management of an effluent treatment plant to deal with the trapped leachate to prevent downstream water contamination. Although the attempt to trap and treat leachate is itself a significant improvement in landfill design, there are a number of practical problems with this approach. Leachate treatment methods at the present time can achieve a reduction, but not complete elimination of contaminants in discharged water (Senior and Shibani 1990; Doedens and Theilen 1992). Further, the treatment of leachate, even with the help of advanced technology, produces waste residues in the form of sludge or dry solids which are classified as hazardous. The management of these hazardous residues needs to be investigated in respect of available disposal options and the need for special landfill sites. Presently, it is common practice to return residues from leachate treatment to landfills in the form of dehydrated sewage sludge.

3.4 POTENTIAL DEMAND FOR ORGANIC WASTE COMPOST

Arguments for composting organic waste needs to take into consideration the economic viability of the recycling scheme. This in turn is dependent on the availability of markets for the finished compost.

The quality of the finished compost, which depends on the process control in composting (discussed in Chapter 4), can vary from a high to a low grade and influence the availability and types of markets. There is, however, a great deal of potential demand for both grades of compost. Their uses can be categorised as fertilisers, soil additives, potting mix, mulch and as soil amendment.

There are currently a number of existing and undeveloped markets, which have the potential to be attracted to the compost products made from organic waste. These include the horticulture industry, nurseries, the home gardener, landscaping services, the agricultural sector and the silviculture industry.

The horticulture industry has the potential to be the largest market for high-grade organic waste compost. The industry's dealing in the production of fruits, vegetables, flowers and ornamental plants, results in the consumption of large volumes of organic matter. The continuous cultivation of crops means a constant depletion of organic matter from the soils. In order to re-establish and maintain production of their crops, the industry will require on-going supply of organic matter to replenish depleted soils.

The nurseries and home gardener, are the second largest potential markets for high-grade organic waste compost products. Approximately 60 per cent of plants marketed in nurseries are grown in containers (Gouin 1991). This inevitably requires the industry to acquire large volumes of potting mix to ensure on-going production. In addition, the preparation of field grown plants (shrubs and trees) for markets causes a loss of top soils, when the plants are dug, balled and burlapped. It is estimated that in the US, up to 20 tons of top soil is lost (i.e., needs to be replaced) when an average crop is prepared for shipment (Buhr *et al.* 1993).

The home gardener is a market that should not be underestimated. These consumers use mulch, soil amendments, top soil and potting mix. This market demand could be met with organic waste compost products. The high grade quality compost has the potential to meet their needs with regards to top soils and potting mixes, while, chipped and shredded yard and green waste could be promoted as mulch.

Agricultural uses of compost include soil conditioning, fertiliser, disease control and erosion control. Compost has the advantage over chemical fertilisers in that it increases drainage in soils and improves soil structures. Recent studies have also established the disease suppressive qualities of compost (Logsdon 1993; Prince 1997). This offers the potential for a significant reduction in the use of pesticides and cost savings.

Demands for low-grade compost are expected from existing markets as well as undeveloped markets. The landscaping industry requires soil amendments as well as top soil for establishing both new landscapes and plants. When establishing new landscapes, landscaping contractors tend to generally purchase soils in large quantities (i.e., truck loads) (Buhr *et al.* 1993). The cost involved in purchasing large quantities would be a factor to influence contractors to utilise low-grade compost.

Undeveloped markets for organic waste compost includes councils, which need soils to cover refuse in landfills and rehabilitate landfills, government funded projects such as Landcare and erosion control schemes and the silviculture industry. The compost used in silviculture industry, such as the forestry industry in Tasmania, could be used as mulch and soil conditioner, for weed control, as well as to prevent soil erosion in replanted logging coups.

3.5 THE DILEMMA

The waste management systems provide a blueprint for waste disposal authorities to manage and release waste in a more environmentally sustainable manner. The challenge is for waste disposal authorities to ensure that comprehensive solutions, as set out in the hierarchy of strategies, are pursued in entirety and with the aim of achieving real reduction in the release of waste.

The priority placed on an issue by the government of the day is an important factor, which can influence the determination of relevant authorities and individuals to ensure that solutions are carried out with the required level of attention. However, since governments have a poor reputation when it comes to pursuing non-economic orientated issues (Walker 1992), waste management is unlikely to receive the level of high priority it needs. In these circumstances, there is a danger that there will not be sufficient motivation within waste disposal authorities to pursue the entire range of strategies proposed in the waste management system. Hence waste disposal authorities might be inclined to accept a minimum level of environmental improvements which meet community demands and to implement partial solutions.

Improvements in landfill technology can be used to imply that landfilling *per se* is environmentally safe, and to exploit the popularly held myth that poor landfill design of the past was the primary cause to the problems of waste disposal (Glover 1995). Waste disposal authorities have reportedly used such tactics to allay community concerns with landfill issues in the past (National Center for Resource Recovery 1974). Furthermore, waste disposal authorities may argue that landfilling a large proportion of waste is justified where resource recovery opportunities are absent, as caused by the unstable markets for recovered materials and the fledgling resource recovery infrastructures which limits resource recovery to a limited range of materials.

There is a lack of expertise, experience and confidence on the part of waste disposal authorities with regard to the management of composting operations. While these agencies possess a great deal of knowledge when it comes to the more traditional aspects of waste collection and disposal, different expertise is required for the composting of organic waste.

In addition, there is still the issue of establishing infrastructure for composting. The existing infrastructure was designed for the old 'cart and bury' waste disposal methods. Changing this infrastructure and developing facilities to meet the needs of composting operations would require innovative thinking and initial capital outlays. With the exception of the wealthier urban areas, establishing composting operations would be beyond the financial ability of most small rate base and rural municipalities.

There is also the concern over compost produced with municipal solid waste. Since municipal solid waste consists of all types of waste there is a possibility of contaminants and toxins ending up in the finished compost. Further more, "garbage" a term, which evokes a negative perception in the minds of most people, could make compost produced from municipal solid waste less appealing than the present commercially available compost.

3.6 CHAPTER SUMMARY

Landfills are an ineffective means of disposing organic waste, as has been demonstrated in the previous sections. The advancements made in landfill management have only succeeded in limiting, but not in preventing pollution problems caused by organic waste disposal. Although the improvement of landfill technology and management is a worthwhile aim in itself, priority in the waste management sector should be given to waste reduction measures. The diversion of organic waste materials from landfills to composting facilities will not only be in accordance with the national emphasis to reduce waste entering landfills but also offer significant environmental as well as economic benefits.

The environmental benefits include:

- a reduction of waste that needs to be released into the environment;
- the prevention of biogas and leachate emissions arising from landfill; and
- a reduced reliance on the natural environment for organic matters in the production of compost.

The economic benefits of recycling organic waste will be realised through:

- reduced waste disposal costs (i.e., reduced reliance on technological fixes for landfill issues);
- savings in landfill space thereby extending the life span of disposal sites; and
- profits from the sale of compost.

The important issue at present is not to lose sight of the aims of the waste management system (i.e., to actively encourage waste reduction over disposal). To achieve this, waste disposal authorities must ensure that the established strategies are put in place and that the objectives enshrined therein are strongly enforced.

This Chapter investigated the problems associated with landfills and examined the rationale for the composting organic waste. It also examined the waste management systems and the problems associated with the implementation of its strategies. This fulfils the objective to examine the current issues with landfilling and establish a rationale for bioconverting organic waste into compost. The following Chapter will investigate what is entailed in composting organic waste.

4. THE BIOCONVERSION (COMPOSTING) OF ORGANIC WASTE

4.1 INTRODUCTION

This Chapter will clarify the complexities of the composting process by examining the ecology of composting and the various technologies employed to provide the controls needed to produce proper compost from organic waste.

The word 'composting' generally conjures up an image of a pile of organic material rotting away in a corner of a household garden and expected to eventually result in compost. This notion is quite different from composting under controlled conditions. Although a rotting pile of organic matter undergoes a natural biological decomposing process, it is also a breeding ground for pathogenic micro-organisms. Compost produced in this manner is potentially unsafe for plants, animals and humans (de Bertoldi and Zucconi 1987). Composting under controlled conditions has the objective of producing compost that is safe to use as a soil conditioner and fertiliser. The concept is akin to the production of other biological products such as beer, wine or cheese, in which the materials and conditions are controlled to achieve the desired outcome (Mathur 1991).

Poor planning and management of a composting operation can lead to the production of low quality compost. Ensuring the quality of the compost is of utmost importance as it ensures markets and the financial viability for the whole operation. In addition to producing a poor quality product, inadequate planning and management can also cause other problems. For example, the municipality of Portland in Oregon USA, was forced to close down their organic waste recycling operation, which had cost some $US25 million to establish, due to odour complaints from nearby neighbours (Handreck 1992).

A clear understanding of composting processes and operations is therefore essential for the proper planning and management of an organic waste recycling operation.

4.2 THE ECOLOGY OF COMPOSTING

4.2.1 THE MICROBIOLOGY OF COMPOSTING

In the natural environment, both micro- and macro-organisms carry out the decomposition of organic materials. Larger organisms assist with the physical size reduction of the organic material but the primary organisms involved in the chemical decomposition of organic matter are micro-organisms, including bacteria, actinomycete and fungi. Micro-organisms are heterotrophic feeders and consume the organic compounds by one of the following processes: parasitising on other living micro-organisms; ingesting inanimate particulate matter; and absorbing both soluble organic nutrients and insoluble carbonaceous materials (Alexander 1971).

4.2.1.1 BACTERIA

Bacteria constitute the most important group of microbial decomposers. This is largely due to their ability to reproduce rapidly on soluble proteins and readily available substrates but also due to their tolerance for high temperatures (Miller 1991). There are three groups of bacteria (i.e., psychrophilic, mesophilic and the thermophilic), which are set apart by their optimal environmental temperatures. The psychrophiles are cool temperature bacteria, active in the range 17°C to 30°C. The mesophiles are mild temperature bacteria, which become active at temperatures around 10°C and optimal at 30-40°C, and are deactivated at temperatures above 45°C. The thermophiles become active when temperatures in the compost pile rise above 45°C and withstand temperatures of up to 70°C. The most commonly reported bacterial species found during composting are *B. subtilis, Bacillus coagulans, B. licheniformis, B. spharicus,* and *B. stearothermophilus* (Miller 1991).

4.2.1.2 ACTINOMYCETE

Actinomycete is slowing growing filamentous bacteria, which prefers moist and aerobic conditions. They are present in the mesophilic temperature range (28-37°C) but at these temperatures cannot compete with the mesophilic bacteria. Their activity peaks in the thermophilic temperature range (55-65°C), when there is less competition for substrates.

The micro-organisms are also known to exhibit extensive growth in later stages of composting (curing stage) when they utilise the remaining more complex organic materials such as cellulose and hemicellulose. Actinomycetes are especially recognised for producing the compound 'geosmine' which is responsible for the pleasant, earthy smell of mature compost (de Bertoldi and Zucconi 1987). The most common actinomycete genera found during composting are *Micromonospora, Streptomyces and Thermoactinomyces* (de Bertoldi and Zucconi 1987; Miller 1991).

4.2.1.3 FUNGI

Fungi can feed on a variety of organic substances, ranging from simple to very complex compounds. They are active in the first stage of decomposition when there is a readily available supply of simple compounds but cannot survive temperatures exceeding 50°C. As for the actinomycete, fungal activity peaks during the declining stage of decomposition as the temperature in the pile drops again. Many species of fungi have the ability to develop over a wide pH range (Alexander 1977). Species of fungi, which have been found during composting, include *Mucor pusillus, Chaetomium thermophilum, Talaromyces (Penicillium) dupontii, T. thermophilus, Thermoascus aurantiacus, Aspergillus fumigatus and Humicola grisea* (de Bertoldi and Zucconi 1987; Miller 1991).

4.2.2 THE COMPOSTING PROCESS

Organic materials are made up of simple and complex chemical compounds, which include starch, organic acids, fats, soluble sugars, cellulose, hemicellulose, protein and lignin. The decomposition of organic matter occurs in two broad phases. Decomposition begins rapidly with the readily available simple compounds and then slows down with the break-down of more complex compounds (de Bertoldi and Zucconi 1987)

Fungi and psychrophilic bacteria begin the decomposition process by utilising the large supply of simple compounds present in a fresh compost mix. They consume the carbonaceous substrates by oxidising the soluble sugars, proteins, starches, organic acids and alcohol. Insoluble compounds are hydrolysed to form soluble compounds and are then absorbed and used intracellularly by the micro-organisms (Mathur 1991). The supply of readily available nutrients allows rapid microbial reproduction and population growth. As these are exothermic processes, the high metabolic activity generates heat leading to an increase in the temperature of the pile, which may reach 70°C or more.

The temperature inside a pile is dependent on the pile's ability to retain the heat. In well insulated piles, temperatures frequently reach >40°C within 2-5 days (Mathur 1991). At this phase of decomposition, the consumption of oxygen and the production of carbon dioxide are high. Oxygen is used by the micro-organisms for respiration and for oxidising the substrates. Carbon dioxide is the resulting waste product of the microbial metabolism.

The high temperature thermophilic bacteria continue the decomposing process order in high temperature conditions. The thermophiles feed on the by-products of hydrolysed polysaccharides, decaying micro-organisms, complex chemical compounds and the remainder of readily available organic compounds.

Elevated temperatures can be both beneficial and detrimental for composting. The beneficial effect is when pathogens and weed seeds are destroyed promoting the sanitation of the end-product. The detrimental effects are that excessively high temperatures can kill most of the thermophilic micro-organisms present and thus stall the decomposition process. Only a few thermophilic bacteria of importance in the composting process are known to withstand temperatures above 70°C (i.e., *Bacillus subtilis, Clostridium sp. and Thermus sp.*) (de Bertoldi and Zucconi 1987; Miller 1991). For decomposition to continue uninterrupted at the thermophilic stage, it is essential for temperatures to remain stabilised at between 55 -65°C.

After decomposition has passed through the thermophilic stage the organic materials are no longer recognisable in their original form. As the substrates in the pile are used up microbial activity slows down, thereby leading to a reduction of heat in the compost pile. This generally indicates that the decomposition is complete and the organic materials are converted to compost. However, the fresh compost may still contain resistant and toxic compounds produced from the earlier stages of decomposition, undecomposed or partly decomposed materials, as well as intermediate metabolic by-products (de Bertoldi and Zucconi 1987; Mathur 1991; Warmer Factsheet 1991;

Handreck 1992). At this stage, the milder temperature micro-organisms return and continue to decompose the remaining undecomposed substrates in the pile.

Actinomycete and fungi dominate at this stage and decomposition will continue until a stable stage is reached and the C:N (carbon, nitrogen) ratio is decreased to about 10:1. The mature compost is safe for use as a plant growing media.

The period taken for the fresh compost to reach maturity is called the stabilisation or curing stage of composting, and can take several weeks to several months. This stage also signifies the beginning of the slow process of humification, involving the condensation of the oxidised by-products, amino acids, peptides, N-compounds, microbial metabolites or products of other aromatic substances in the detritus to form humus (Mathur 1991; de Bertoldi and Zucconi 1987).

4.2.3 Achieving Optimum Conditions for Composting

A number of factors can influence the decomposing process. Those of primary importance are the supply of oxygen, moisture, C:N ratio and temperature. Other factors, which come into play, are the physical size of the compost pile, the pH and the size of the organic particles. These factors can play a crucial role in either inhibiting or speeding up the process.

4.2.3.1 Oxygen

Oxygen is essential for microbial activity throughout the composting process. The supply of oxygen will determine the type of decomposition, microbial growth and metabolism, and the rate of decomposition (de Bertoldi and Zucconi 1987; Mathur 1991; Miller 1991; Hamelers 1993).

The supply of oxygen in a compost pile determines whether aerobic or anaerobic conditions prevail. Where oxygen supply is restricted, anaerobic decomposition sets in with the activation of anaerobic micro-organisms, whereas the abundance of oxygen ensures the activation of aerobic micro-organisms. Aerobic decomposition is preferred over anaerobic decomposition, as anaerobic decomposition produces methane, which is a known environmental pollutant and contributes to nuisance odours. Other disadvantages of anaerobic decomposition are that the process is slower, and the temperature, lower, which does not allow for the sanitation (the destruction of pathogens and weed seeds) of the end-product.

Micro-organisms use oxygen for respiration and microbial metabolism. The amount of oxygen needed during composting is therefore dependent on the rate at which microbes utilise the feedstock in the compost pile. For instance, increased microbial activity at times of abundant supply of readily useable substrates, such as in the initial stage of decomposition, leads to an increased oxygen demand. During the stabilising or curing stage of decomposition, when less substrate is readily available as feedstock, the oxygen demand is reduced. It is suggested that a concentration of 5 to 18 per cent oxygen in the circulating air of the compost pile is needed as an optimum (de Bertoldi and Zucconi 1987; Mathur 1991; Miller 1991).

Oxygen consumption has been shown to be linearly related to the generation of heat during decomposition (Hamelers 1993). Even if aerobic conditions are maintained, restricted oxygen supply can prevent the development of high temperatures in the pile. This might lead to insufficient disinfection of the material.

4.2.3.2 WATER

Water is essential for decomposition as most microbial activity occurs in the thin film of moisture covering the surface of the organic particles (Mathur 1991). The micro-organisms use water to dissolve nutrients and substrates that can only be absorbed as a solution. In addition, water also acts as a transport medium for free enzymes and motile micro-organisms (Mathur 1991).

Moisture and oxygen levels in the compost are closely interrelated. For the activation and survival of aerobic micro-organisms, the spaces and pores between the organic particles need to be occupied by both air and water. Excessive moisture levels can restrict the flow of oxygen in the pile by clogging up the pores and spaces between particles. On the other hand, if the moisture level is too low, premature dehydration can occur in the pile and stall the decomposition process (de Bertoldi and Zucconi 1987). The level of moisture is influenced by factors such as the moisture content of the decomposing organic materials and the climatic conditions, which the compost pile is exposed to.

The water holding capacity of organic materials such as vegetable waste, green plants, fruits and sewage sludge are high compared with materials such as wood waste, branches and dried leaves. Other materials, such as paper and disposable nappies, have the capacity to hold high moisture content on wetting. Compost piles, which contain a large proportion of substances that have a high water holding capacity, may not require the addition of moisture. However, compost piles with a larger proportion of organic materials that have low water holding capacity may require regular wetting.

In arid or low rainfall areas, high moisture losses through evaporation will occur. Occasional wetting of the pile may thus be needed to ensure that adequate moisture levels will be maintained. On the other hand, composting in temperate regions and high rainfall areas may result in excessive moisture levels in the compost pile. Under those conditions, the removal of the excess moisture will be required. This can be achieved by frequent turning or mixing of the compost or enclosing the whole pile in an enclosure (Mathur 1991). Studies reveal that moisture levels ranging from between 50 to 75 per cent in the compost pile are appropriate for composting most waste materials (de Bertoldi and Zucconi 1987; Mathur 1991; Miller 1991; Warmer Factsheet 1991).

4.2.3.3 C:N RATIO

Carbon rich materials can generally be identified by their brown colour and woody texture such as branches, timber products, dried leaves and straw. Nitrogen rich materials tend to be green and have high moisture content, such as fruits, grass clippings and vegetables. The different materials need to be mixed thoroughly so that the C:N ratio is uniform throughout the compost pile. An appropriate C:N ratio is essential in composting for two reasons. Firstly, it ensures the adequate supply of nutrients for the micro-organisms, which in turn promotes rapid composting. Secondly, it ensures the conservation of nitrogen, which is an important characteristic in terms of the fertiliser value of the compost (Gotaas 1956; Alexander 1977; Mathur 1991).

Carbon is used by micro-organisms to synthetise protoplasmic constituents, while nitrogen is used for growth (Alexander 1977). Only a fraction of the total amount of carbon and nitrogen contained in the organic material is accessible or available to the micro-organisms. Some of the carbonaceous substrates, for example cellulose and lignin, are very resistant to biological breakdown and contribute little to the pool of available nutrients (Gotaas 1956). Between 20 to 40 per cent of the substrate carbon is assimilated by the micro-organisms, while the remainder is released as carbon dioxide or accumulated as waste products in the compost.

In order to ensure the adequate supply of nutrients, a C:N ratio of above 30:1 at the start, has been suggested for optimum composting conditions. This figure is consistent with the metabolic rate of micro-organisms, which utilise on average 30 parts of carbon per 1 part of nitrogen (Gotaas 1956; Mathur 1991). C:N ratios suggested in other literature sources for successful composting range from between 25:1 to 40:1 (Hughes 1980; de Bertoldi and Zucconi 1987; Warmer Factsheet 1991).

If the C:N ratio is too high, microbial growth will be inhibited by the lack of available nitrogen. In such situations, microbes will resort to recycling nitrogen stored in the cells of dead micro-organisms or focus on utilising complex compounds to supplement the required nitrogen level. Both means will provide the micro-organisms with nitrogen, however, as long as the nitrogen supply is limited, microbial growth will be restrained, and the decomposition process is slowed down.

At the other end of the spectrum, if the C:N ratio is too low, the micro-organisms will utilise the available carbon and dispose of the excess nitrogen. In this case, nitrogen will be lost to the atmosphere either as ammonia or another nitrogenous gas (Gotaas 1956; Alexander 1977). The loss of nitrogen as ammonia can be considerable when the pH in the compost pile is high (Gotaas 1956; de Bertoldi and Zucconi 1987; Mathur 1991).

4.2.3.4 pH Level

The pH in the compost pile can influence microbial activity and hence the decomposition process. Micro-organisms have a specific optimum pH for growth and proliferation. The activity of bacteria and actinomycete for example are high at pH levels between 7.1 to 7.6, but decline when the pH levels drop (Alexander 1977). Fungi, although tolerant to pH levels ranging from highly acidic to alkaline extremes, dominate at low pH levels. The optimum levels for most micro-organisms are in the neutral range, between 5.5 and 8 (Alexander 1977; de Bertoldi and Zucconi 1987).

Minor fluctuations in pH levels, which are known to occur naturally in compost piles, should not affect the overall composting process. Decomposition of organic matter continues to take place over a wide pH range (i.e. from 3 to 11), as various micro-organisms with different pH optima complement each other. Extreme pH levels however can cause the decomposition process to cease. It can influence the selection of micro-organisms (Mathur 1991) and reduce overall microbial activity.

The pH level can be managed during composting to prevent extreme levels from occurring (Alexander 1977; Mathur 1991). The addition of lime will raise pH levels when acidic conditions prevail, whereas sulphur can be utilised to lower the pH levels when alkaline conditions prevail. However, these practices are only recommended when extreme acidic or alkaline conditions occur, and not for the control of short-term and spatial variations which fall within the normal range of pH fluctuations (de Bertoldi and Zucconi 1987).

4.2.3.5 TEMPERATURE

Temperature affects the composting process in several ways. Firstly, the external temperature which is governed by climatic conditions can significantly influence the internal temperatures of a compost pile. For instance, external temperatures of below zero may lead to the freezing of the decomposing materials while in the summer months excessive moisture loss may occur as a result of high evaporation (Strauch et al. 1995). It is possible to minimise the effects of external climatic conditions by the siting of compost piles (e.g., inside well insulated buildings).

Internal temperatures of the compost pile are indicative of both the progress and the effectiveness of the composting process. Temperatures rise as the heat generated by microbial activity accumulates inside the compost pile. Retention of this heat inside the pile favours the thermophilic micro-organisms and is associated with an increasing rate of decay (Alexander 1977; Miller 1991). The abundance of enzymes produced by micro-organisms to dissolve complex compounds is known to double with each 10°C rise in temperature (Miller 1991).

High temperatures in the compost are desirable as they facilitate the sanitising of the finished compost through the destruction of lower temperature micro-organisms. This phenomenon is generally described as the 'thermo-killing' effect. The continual heat generated for 2-3 days which accumulates inside the pile is sufficient to eliminate most pathogens and weed seeds. However, excessively high temperatures are not recommended as they may cause excessive evaporative water loss (Mathur 1991). In addition, temperatures beyond 70°C can work against the decomposition process by de-activating micro-organisms and enzyme production. It has been suggested that the optimum temperature for high rate decomposition lies between 50 and 60°C (Mathur 1991; Miller 1991).

4.2.3.6 VOLUME OF COMPOST PILE

Aerobic microbial activity can be inhibited by either too small or too big compost pile. A small mass of organic matter may not contain adequate C:N ratio needed by the decomposing micro-organisms, and may result in lower microbial growth and activity, hence a reduced rate of decomposition. On the other hand, a large mass provides more substrates for microbial growth and proliferation. It also enhances insulation of the compost pile from the ambient environment and thereby reduces heat loss. However, if a compost pile is too big, materials in the bottom of the pile may get compacted by the weight of the material above, restricting the movement of air and moisture. The ideal height of compost piles to achieve optimum composting is between 1 to 2 meters (Mathur 1991; Warmer Factsheet 1991).

4.2.3.7 PARTICLE SIZE OF ORGANIC MATTER

The size of organic matter in a compost pile can influence the movement of water and air in the compost pile. Particles which are large tend not to pack close together. Small particles allow for narrower interstitial spaces between particles and provide micro-organisms with greater surface area to work on. However, narrow interstitial spaces may restrict movement of air and water through the interparticule spaces and a heterogeneous mix of particle sizes is therefore recommended (Mathur 1991). Heterogeneity of particle size can prevent particles packing tightly together and offers both micro and macro pores between particles. Micropores, depending on the moisture levels of the pile[1], can hold water and air for microbial activity to take place. The macropores act as a medium

[1] Excessive moisture levels would need to be prevented as it could cause water log conditions and lead to anaerobic decomposition.

for the ventilation of gases such as carbon dioxide (which is produced during decomposition) and oxygen, as well as for the removal of excess water.

4.3 PROCESS CONTROL FOR COMPOSTING ORGANIC WASTE

4.3.1 SEPARATING THE ORGANIC FRACTION FROM THE NON-COMPOSTABLE WASTE

Municipal solid waste comes in all shapes and sizes and its composition varies from season to season as well as from load to load. Some of the materials will be suitable for composting while others are not and may contaminate and affect the quality of the compost. Separating compostable waste from non-compostable waste can be achieved either by mechanical/hand sorting or through a source separated collection service. Both of these methods are discussed below.

4.3.1.1 MECHANICAL/HAND SORTING

There are a number sorting facilities in operation in the US and the European Union (Hughes 1980). In some facilities, sorting is completely automated while in others, sorting is carried out by a combination of both machines and hand sorting.

Sorting is carried out in two phases. In the first phase, the larger and more easily extractable materials are removed. This involves placing incoming municipal solid waste on conveyor belts and passing it through various mechanisms. The mechanisms rip open garbage bags and sieve larger materials out. The waste is then passed under static electromagnets to remove any ferrous metals. X-ray fluorescence or similar sensor controlling air jets are then used to blow out contaminants such as plastics. This last stage is sometimes carried out by hand.

In the second phase, the partially sorted waste is passed through a shredding and grinding process. The shredded and ground materials are then put through a high rate composting process in enclosed reactors which takes 2 to 4 days. Conditions in the reactor are optimised to encourage enhanced decomposition of the organic matter in the waste. While 2 to 4 days are insufficient time for proper composting to take place, temperatures can rise sufficiently to sanitise and convert the organic matters into smaller, more homogeneous particles (de Bertoldi et al. 1985). The materials from the reactors are than screened to separate the smaller particles (4 cm in size and below), from the rest of the waste (Hughes 1980). The larger materials are rejected and landfilled while the smaller particles are transferred to composting sites for proper composting.

Although mechanical and hand sorting mechanisms have the proven capacity to separate compostable waste from the non-compostable fraction, they are also noted for their limitations. Apart from the obvious high establishment and operational costs, they are especially noted for their ineffectiveness to separate all contaminants from the organic waste. Visible contaminants, such as broken glass and pottery, which escape the screening process end up with the compostable materials. In addition to the visible contaminants, there is also the issue with less visible contaminants, such as liquid hazardous waste, which the facilities have no control over. All these contaminants can lower the quality of the end product.

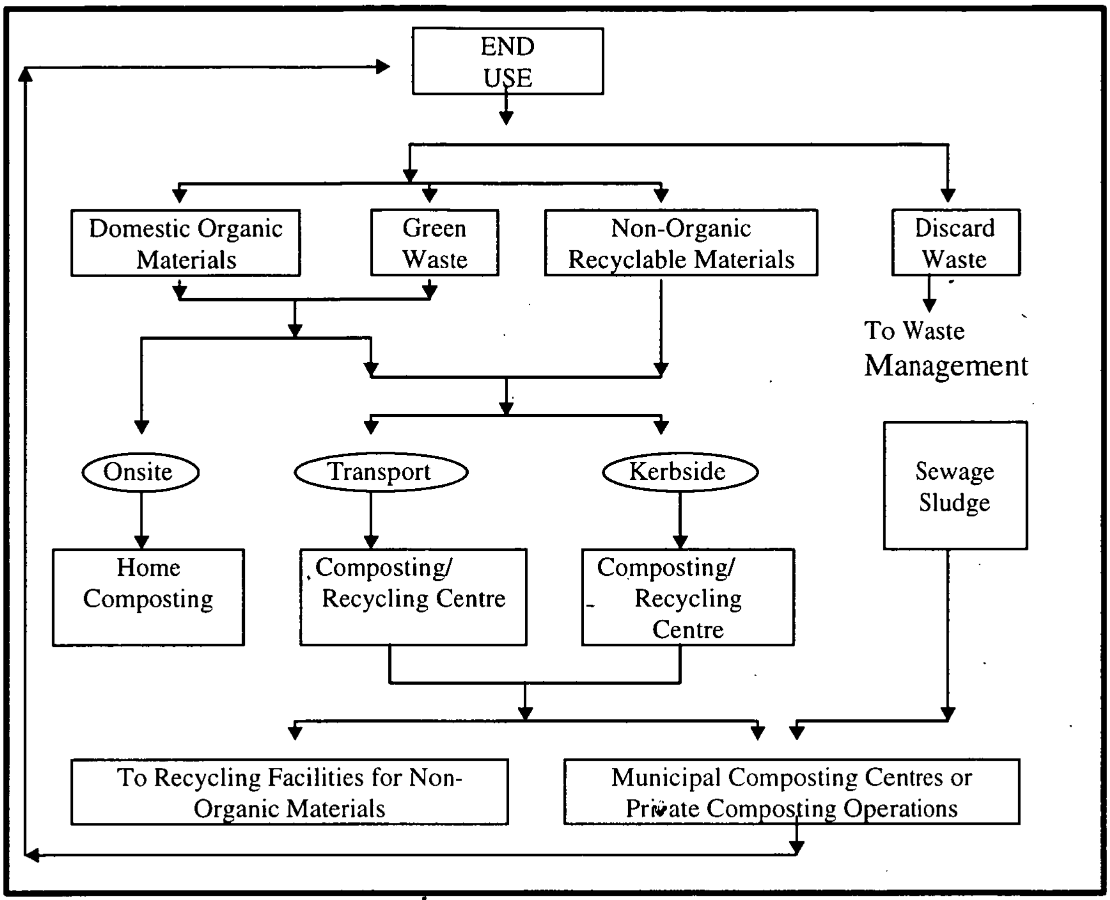
Concern for the irreversible contamination to agricultural land had led some Governments in the European Union to mandate source separate collection service, which resulted in the shut-down of many sorting plants (Handreck 1992). Other than the problems of contamination, overseas experience also indicates that sorting waste in such facilities can be a potential health hazard to workers (Jager *et al.* 1994; Marchand *et al.* 1995; Millner 1995; Poulsen *et al.* 1995).

4.3.1.2 SOURCE SEPARATED COLLECTION SERVICE

The concept behind source separation is to separate the compostable fraction from the non-compostable fraction right at the source, for example the home. Domestic waste is separated into categories of dry recyclables, paper, green waste, domestic organic waste and discard waste, and placed into separate bins by the householder. The green and domestic organic waste is then collected via a separate collection service. This reduces the potential for other waste to come in contact with the organic materials. Trials carried out in the US and the European Union confirm the effectiveness of this method (Fricke and Vogtmann 1993; Kirchmann and Widen 1994). Compost produced from source separated organic waste was found to be of a higher quality with much lower levels of heavy metal contamination, than compost produced from mechanically/hand sorted waste.

In order to take advantage of the benefits of source separation, an integrated approach to waste collection is required. Figure 4.1 shows a model of such an integrated collection system.

Figure4.1: A model of an integrated approach to separate collection of waste



(Source: adapted from Society of Environmental Toxicology and Chemistry 1991)

Sewage sludge, which has a high organic content, is also suitable for composting. However, appropriate measures must be taken to ensure that the sewage is appropriately treated and contaminants such as heavy metals are within nationally acceptable levels.

Source separation is also preferred over mechanical/hand sorting due to its cost advantage. The cost involved in operating a separate collection for organic waste is counteracted by the reduced number of normal waste collection trips needed for the collection of non-compostable waste.

4.3.2 SHREDDING AND GRINDING

Since municipal solid waste comes in all sizes, it is essential that the waste components are reduced to a size that is manageable and suitable for composting. Shredding and grinding assists in this by reducing the size of organic waste particles to 4 to 6.5 cm (Hughes 1980). Shredding and grinding organic waste also offers several other advantages in composting.

Firstly, it achieves volume reduction, especially where yard or park waste and timber are involved. A mobile shredder towed at the back of a truck could be used to shred the bulky materials to pieces thereby increasing the convenience of transporting the waste. In addition, it eliminates the need for further management at the composting facility. Secondly, shredding and grinding in mechanical/hand sorting facilities would ensure that any contaminants (e.g., broken glass and pottery), which had escaped the screening process is reduced to powdered form. This means that these contaminants become visually less intrusive (Nordstedt *et al.* 1993), although it is recognised that the quality of the compost is affected. Compost produced in this manner should be clearly identified as a lower grade and its use restricted to uses such as land reclamation, building road shoulders or rehabilitation of old disposal sites.

There are several types of shredding and grinding equipment in use. The most commonly used shredder is the mobile shredder. Fitted on a truck, it can be used to conveniently shred yard or park waste at the collection point. The most common type of grinder is the hammermill. The hammermill, which consists of swinging hammers revolving around a shaft, hammers waste materials through a system of grids (Hughes 1980)

4.3.3 *Heat Management in Composting*

There are several ways in which excess heat can be removed from a compost pile. In small scale non-aerated static pile composting systems, heat management can be achieved by manipulating the design and size of the pile. Small piles with a larger surface area provide for rapid heat loss to achieve equilibrium with the ambient air temperatures.

For large-scale aerated composting systems there are two ways in which the excess heat can be removed from the compost pile. One is to force air through the composting materials and the other is to pass the materials through air. In the aerated static pile system, heat management is achieved by using the same mechanism that is used to aerate the pile. Air circulation is increased to remove excess heat when overheating occurs inside the pile (Miller 1991; Warmer Factsheet 1991). This system also offers the additional advantage of distributing the heat throughout the pile before it is released to the ambient air. Heat loss is achieved by controlling the amount of air flow through the pile.

In the windrow composting systems, heat loss can be achieved by turning the compost pile, allowing for the materials to pass through the air. Turning however is not an effective mechanism for managing heat, as it does not allow for control over the degree of heat loss. In turning, the whole pile is broken up, resulting in excessive loss of heat to the surrounding air.

In the higher technology systems, heat management is carried out through the use of turning and ventilating mechanisms. The turning mechanisms inside these systems throw the compost into the air, thereby allowing for the transfer of heat to the air. Ventilating systems supply fresh air, then forces the heated exhaust air out of the system. The process is automated in the high technology systems, with the use of temperature sensors inside the system controlling the amount of air ventilated into the reactor.

4.3.4 PATHOGEN CONTROL

Eliminating infectious pathogens from the organic waste is one of the major objectives of composting. Pathogens in the compost can pose a serious health hazard to humans as well as to plants. See Appendix 1 and Appendix 2 for a (partial) list of pathogens found in organic wastes that are harmful to humans and plants. Pathways for pathogens to enter compost include faecal matter and plant residues. Faecal matter, such as contained in sewage sludge, animal litter and baby nappies, is known to carry viruses, bacteria, enterobacteria, parasites, fungi and animal and human helminth (Farrell 1993). Plant residues can carry fungi, bacteria, viruses and nematodes (Bollen 1985).

Most pathogens are killed during composting by one of three mechanisms: microbial antagonism; toxic effects of conversion products formed during decomposition; and the heat generated during the thermophilic phase (Bollen 1985). In the first two cases, as microbial activity is dependent on factors such as available nutrients, temperatures and moisture levels in the pile, pathogen destruction is difficult to foresee and therefore to control. Pathogen destruction by heat, on the other hand, is easier to determine, as specific inactivation temperatures of pathogens are known. Heat management has thus become the main method for the elimination of pathogens during composting.

In the relevant literature, the time-temperature control method is proposed as the most effective means for the proper elimination of pathogens in compost (Gotaas 1956; Hughes 1980; Stentiford 1993). It has been suggested that for an effective 'pasteurisation-type' killing of the pathogens temperatures in the pile need to be maintained at 55 - 60°C for 3 consecutive days. See Appendix 3 for temperature and time taken for the destruction of some common pathogens.

Special attention may be needed for the elimination of pathogens in static and windrow composting systems. It is noted that composting in these systems may not achieve complete pathogen destruction, as the pathogens living in the cooler outer edge of a pile may not be exposed to the heat concentrated in the middle of the pile (Farrell 1993). There is a general agreement among most authors that if the pile is frequently turned during the early stages of composting, when temperatures are high, the potential for the destruction of pathogen is greater (Gotaas 1956; Hughes 1980; Bollen 1985).

In addition to the elimination of pathogens originally present in the composting materials, it is also essential that the finished compost is inhospitable for their recolonisation. Unstabilised compost, which contains partially decomposed materials, can provide ideal conditions for pathogen regrowth and is also attractive to vectors of pathogens. The emphasis is therefore on the proper maturation or curing of the compost. Fully matured compost, which contains only complex organic molecules, reduces the potential for pathogen revival. Putrefaction and odour generation is also reduced and so is the attractiveness to the vectors of pathogens.

4.3.5 ODOUR CONTROL

4.3.5.1 ODOUR GENERATION

Odorous compounds are inevitably produced during the composting process, either through biological or thermal-chemical reaction, and are primarily emitted in a gaseous form (Van Der Hoek and Oosthoek 1985; Handreck 1992; Miller 1993). The most common compounds contributing to the production of odours are sulphur compounds, ammonia, amine compounds, acetone, phenol and toluene (William and Miller 1993). The organic sulphur compounds produce odours of a very pervasive nature, which has been described as 'dead animal smell'. Ammonia is another compound, which generates intense on-site odour. Odours produced under anaerobic conditions are more persuasive than aerobic conditions. Volatile fatty acids, the intermediaries resulting from the carbohydrate metabolism, accumulate under anaerobic conditions are fairly volatile. Their by-products such as phenol, andaldehydes, ketones and ethanol are recognised as possessing strong and unpleasant odours (Van Der Hoek and Oosthoek 1985; Miller 1993).

4.3.5.2 ODOUR EMISSIONS FROM COMPOSTING SYSTEMS

In passive and low aerated composting systems such as the static and windrow composting systems, malodorous intermediate and end products are carried out with the natural air flow of the pile (Baeten and Verstraete 1993). Odours emitted in this manner are usually minimised, as the exhaust air is filtered by the outer layer of the compost pile and also because the volume of the moving air is low. However, increased odour emissions become evident when the compost piles are turned as the inner layers are exposed and odorous compounds released. In aerated composting systems ventilated exhaust air carries the odorous compounds out into the environment.

4.3.5.3 ODOUR MANAGEMENT

It may be difficult to completely eliminate odours during composting, however, if managed carefully nuisance odour problems can be minimised. Odour control could be achieved by firstly optimising composting processes and secondly by containing and treating the odorous air generated. In the static pile and windrow composting systems, which are prone to creating anaerobic pockets, aeration necessitates regular turning during the initial phases of composting. The increase in the supply of oxygen maintains aerobic conditions and encourages continued decomposition of the odorous compounds.

Containing and treating odours in aerated composting systems can be achieved in several ways. In open composting systems where air is blown through the decomposing materials, odour reduction is achieved by filtering the odorous compounds from the exhaust air, by covering the pile with a biofilter, such as mature compost. Other biofilters include heather, mature compost, filamentous peat and moist bark. Filtration occurs as the odorous compounds are adsorbed onto the moist and solid phases of the filtering organic material, on which microbial degradation take place (Van Der Hoek and Oosthoek 1985). Biofilters are effective in removing most organic and inorganic gases, however they are known to have limited capacity when it comes to filtering ammonia and dimethyl sulphide (William and Miller 1993).

In open composting systems where air is drawn through the composting materials, the odorous compounds can be filtered by directing the contaminated exhaust air through biological or chemical filtering systems. Likewise, contaminated air inside in-vessel composting systems, can be passed through filtering systems before being released into the environment.

Chemical filtration systems are more effective in treating all odours (Dunson 1993). Removal of the odours compounds is achieved firstly by scrubbing the contaminated air with an acid (such as sulphuric acid), followed by an alkaline oxidant (such as sodium hypochlorite or potassium permanganate). A major disadvantage with chemical filters are the establishment and operational costs, including consumable chemicals.

4.3.6 Stabilising the Compost (Compost Maturity)

4.3.6.1 Issues Associated with Immature Compost

Assessing the maturity of the compost is important, as it determines the safe use and influences the quality of the product. Immature compost can be detrimental to plant growth, causing delayed growth and suppressed seed germination. Research indicates that the following problems can occur when immature compost is used for growing plants (Chen and Inbar 1993).

- Pythotoxicity: A number of undecomposed compounds in the fresh compost contribute to the pythotoxic effects. These include organic acids (acetic, propionic and butyric) and allopathic toxins. These toxic compounds can easily be eliminated when the fresh compost is allowed to stabilise over a period of time.

- Oxygen deficiency: Oxygen deficiency results when microbes which continue to decompose the remaining substrates in the immature compost, compete with plant roots for the available oxygen. This can cause oxygen deprivation to the roots of the plants.
- Nitrogen deficiency: Where there is a high C:N ratio in the immature compost, microbial activity will continue to utilise the available nitrogen. This could deprive the plants of access to the nitrogen.

4.3.6.2 Testing for Compost Maturity

Since the objective of composting is to convert organic waste to compost, a medium suitable for plant growth, compost maturity needs to be defined in terms of the safe use of the product. Several methods for assessing compost maturity are available (Morel *et al.* 1985; Chen and Inbar 1993) and are discussed below.

- Respirometric test: Oxygen is used by micro-organisms for respiration and the oxidisation of substrates in the compost pile. In this test method the respiration of the compost is measured by identifying the amount of oxygen utilised and the amount of carbon dioxide released by the compost. High respiratory levels indicate that microbial degradation is still occurring, while low respiratory levels indicate a levelling off of metabolic activity and substrates consumption. Research shows that oxygen consumption of less than 40 mg per kg of dry matter per hour indicates that the compost is mature (Morel *et al.* 1985).
- C:N ratio: This is commonly used to measure compost maturity. The C:N ratio decreases over time as decomposition progresses. The carbon and nitrogen will continue to be utilised until the C:N ratio drops to 10:1, a characteristic equilibrium ratio similar to that of soils, humus and the chemical composition of microbial cells (Alexander 1977). Thus by analysing the C:N ratio at the initial and final stage of composting, the maturity of the compost can be determined.
- Other chemical analyses: During composting, a number of changes occur to the organic materials until stability is reached. These include an increase in ash content and cation exchange capacity and decrease in polysaccharide content (i.e., cellulose

and hemicellulose). The maturity of the compost is determined by testing the cellulose and hemicellulose content and the concentration of humic substances.

- Biological phytotoxicity: Unlike the above methods requiring the use of a laboratory and skilled personnel, this test is simple and can be conducted by the average composting operator. The test is based on the comparison of plants grown in pure compost and plants grown in compost-soil mix or aged compost. Where symptoms of phytotoxcity are observed using pure compost the compost is considered to be immature. Enhanced plant growth, on the other hand, indicates compost maturity.

Although assessing compost maturity may be an involved process, there is a general consensus in composting literature that the older the compost the more stabilised it is. Compost that is allowed to stabilise over a period of 6 to 12 months is generally considered as safe for use.

4.3.6.3 Processes Involved in Stabilising Compost

The process of stabilising compost involves piling the compost in aerated or non-aerated windrows. To encourage the decomposition of any remaining undecayed materials in this stage, it is essential for the pile to be kept moist and aerated. Stabilising the compost in non-aerated windrows may be a cheaper option, especially when large amounts of compost are involved. However, aerating the piles will reduce the time taken for stabilisation. Depending on the type of materials, aeration can generally reduce the stabilisation period to 2 months (Handreck 1992). Speeding up the stabilisation process offers benefits in terms of the space required for storing the compost, as well as preventing anaerobic conditions from setting in and causing the generation of odours.

4.4 Composting Technology

Due to the high profile given to composting as a viable alternative disposal method for organic waste, there has been a great deal of research into composting technology. High volume fast decomposition rate composting technologies have been developed to deal with the large amounts of organic waste created daily. The two main composting methods to achieve this aim are open composting systems and in-vessel composting systems.

4.4.1 *Open Composting Systems*

In open composting systems, as in the earliest forms of composting, organic materials are piled into a heap and allowed to compost outdoors. A major disadvantage of early systems was that diminishing oxygen levels often created anaerobic pockets inside piles, which not only slowed the decay process but also caused the release of foul odours. However, controls are now readily implemented to manage the conditions inside the pile. The modern open systems utilise low cost technology to ensure aerobic conditions are maintained in the compost pile.

The advantage of open composting systems is their low cost, low technology operation. There are however a number of limitations which can restrict the use of open systems. Since open systems are exposed to the environment, vermin which are attracted to the compost and odours, can be difficult to manage. Comprehensive forward planning is therefore necessary, in particular with regard to selection of sites for open composting systems. The two well known open composting systems are the static pile and the windrow turned composting system.

4.4.1.1 Static Piles

The static pile is the modern version of the earlier open composting system into which low cost technology has been incorporated to improve the decomposition process. In some cases, front-end loaders or windrow turners are used occasionally to turn and aerate the decomposing materials. In others, air is either blown through the composting materials or drawn through the composting materials by means of a suction mechanism. The well known Beltsville Extended Aerated Static Pile system uses aeration pipes placed under the pile, to either blow or draw air through the composting materials (de Bertoldi et al. 1985; Handreck 1992). Temperature sensors inside the pile regulate air circulation. The same mechanism is also used to both prevent overheating and minimise excessive heat loss to the exhaust air. This system also allows for the heat from the more rapidly decomposing regions to be spread to the outer cooler regions (Warmer Factsheet 1991).

It is also possible to manage odours in the aerated static pile system. When air is blown through the decomposing materials, a layer of mature compost placed over the decomposing materials filters odours from the exhaust air, as it leaves the pile. Where suction is applied, the exhaust air is caught and passed through filters to remove the odours, before being released.

4.4.1.2 WINDROW TURNED COMPOSTING SYSTEM

The windrow composting system is another open composting system which uses low cost technology to aerate the decomposing materials. In this system the organic materials are mixed and heaped into elongated piles about 2.5 meters high and 2 to 3 meters wide. The length of the windrows is usually determined by the available space. Unlike the occasional turning of the static pile system, in windrow composting the piles are turned regularly by front-end loaders or more specialised windrow turners. In some cases, in addition to turning, air is forced into the decomposing materials from the bottom. The windrow system is known to be effective in producing a faster product maturation than non-aerated static piles, and a good quality compost (Mathur 1991).

Although the windrow composting system is relatively cheap to operate, it has a number of limitations, notably its poor capacity for odour management. It is therefore essential for operations to be isolated from residential areas by an appropriate buffer zone. Other disadvantages include the cost involved in turning equipment and the dispersal of dust and allergenic spores, which result during turning.

4.4.2 IN-VESSEL COMPOSTING SYSTEMS

In-vessel composting systems use a container in which ideal conditions for the decomposition process can be easily and readily maintained and vary from relatively simple systems to high technology automated control systems. In-vessel composting systems have the advantage of providing insulation from external temperature fluctuations and hence retaining the temperature of the compost pile. Mechanical turners or mixers can be installed inside or outside the system to mix the organic materials.

In the more complex systems, computerised sensors allow fully automated monitoring and control of temperature, moisture and oxygen (Keener *et al.* 1993). Odours produced by volatile organic compounds can be managed by passing the exhaust air through biofilters or chemical scrubbers (Hoitink and Keener 1995).

Although the in-vessel system offers appealing features, it is not a feasible choice for most municipalities. The high technology equipment involves significant capital investment and requires highly skilled maintenance personnel to ensure its successful operation.

There are three main types of in-vessel composting systems, which include: the trough/tunnel/trench systems; horizontal reactors; and the vertical reactors or tower systems. These three systems are discussed below.

4.4.2.1 TROUGH/TUNNEL/TRENCH SYSTEMS

The general design of a trough, tunnel or trench system involves composting in a concrete receptacle which ranges in size from two to four meters width and from two to three meters height. They are in most instances housed in buildings but sometimes in greenhouse-like constructions. A turning mechanism, fitted on the side walls of the system, turns and mixes the composting materials and in some systems moves the finished compost onto a conveyor belt for transport to a storage area. Other features of these systems may be programmed sensors and activators to control temperature and aeration. Aeration is accomplished by forcing air into the materials from pipes placed at the bottom of the system. Biodegradation can be achieved within 21 to 44 days (Handreck 1992; Cevallos *et al.* 1995).

4.4.2.2 HORIZONTAL REACTORS

There are several types of horizontal reactors. Those commonly mentioned in the literature are the Dano, Bedminister, Buhler, Royer and Ewesen facilities (de Bertoldi *et al.* 1985; Handreck 1992). Their physical appearance is similar to horizontal cylindrical silos which are about 3 meters in diameter and over 50 meters long. The waste is loaded, either continuously or in batches, into one end of the reactor and the processed materials are removed from the opposite end. They usually have a turning mechanism which rotates the reactor at approximately 3-4 turns a minute to agitate and mix the organic materials as well as move the materials along to the opposite end. In some systems the materials inside the reactor may only be turned periodically or not at all. Air is ventilated into the reactors to ensure oxygen levels are sufficient for the aerobic micro-organisms. Composting municipal solid waste by this method takes between 3 to 4 days. Although the materials are degraded to the point where they are no longer recognisable in the original form, the time in the reactor is insufficient to produce mature compost. The degraded materials therefore need to be stored to achieve maturation or curing.

4.4.2.3 VERTICAL REACTORS OR TOWER SYSTEMS

The two types of vertical reactors are the silo composting system and the multi floor composting system. These systems have the advantage in that they do not require a great tracts of land to establish, hence suited for large cities. The silo system is a static system in which air is forced through the material from the base. The height of the silo ranges from 4 to 20 meters and biodegradation of organic waste takes 2 to 3 weeks, (de Bertoldi *et al.* 1985; Handreck 1992; Stentiford 1993). Handreck (1992) notes that there is very little support for the vertical silo system due to the difficulty of controlling the conditions.

In the multi-floor system, composting occurs on the different floors of the tower. Organic waste is heaped into piles of 2 to 3 meters height. Aeration is carried out by forcing air through the pile from the bottom. This system has been found to be extremely effective in managing and promoting rapid controlled composting, compared to the silo system (de Bertoldi *et al.* 1985; Stentiford 1993).

4.5 CHAPTER SUMMARY

This Chapter examined the biology of composting, and the various composting methods, composting technologies and the process control, involved in composting organic waste. It clarified the complexities of composting and investigated the process control needed to produce proper compost, from organic waste. This fulfils the objective to investigate what is entailed in bioconverting organic waste into compost. The following Chapter details a methodology for an interview survey and examines the methodical issues associated with carrying out a social survey.

5. SURVEY METHODOLOGY

5.1 INTRODUCTION

This Chapter discusses the methodology for a public survey which was carried out in the municipality of Hobart. The focus is on the design and administration of the survey, including factors that were considered in developing the questionnaire. The aim of the survey was to determine the levels of community support for the recycling of organic waste and the current recycling practices for organic waste. The results are discussed in Chapter six.

The most accurate method of obtaining data about a population is to survey the entire population (de Vaus 1991), which is only practical for small communities. Surveys therefore focus on surveying a group of people (a sample) who reflect the characteristics and responses of the wider population. However, the sample selection must be carefully designed to avoid bias caused by the exclusion or over representation of segments of the population. Sampling bias can significantly influence the quality of the data obtained and restrict the extent to which it can be used to make generalisations about the population (de Vaus 1991). This point is emphasised in the literature on social surveys, and a number of sampling methodologies have been proposed as a guide for researchers conducting social surveys (Mitchell and Carson 1989; de Vaus 1991). Although the terminology varies, the sampling methodologies are generally classified as simple random sampling, systematic sampling, stratified sampling and the multistage sampling methods.

5.2 SAMPLING METHODS

In the selection of the sample for this study, the above mentioned sampling methodologies have been utilised at various stages and involves a three stage process. Firstly, the stratified sampling technique was used to select suburbs within the municipality of Hobart, which reflect the characteristics of the population of the wider municipality. Secondly, the stratifying technique was again used to reduce selected suburbs to specific sample areas based on the 1991 Australian Bureau Statistics census collection districts. Thirdly, systematic and simple random sampling techniques were employed to select the final sample.

5.2.1 THE STRATIFYING VARIABLES

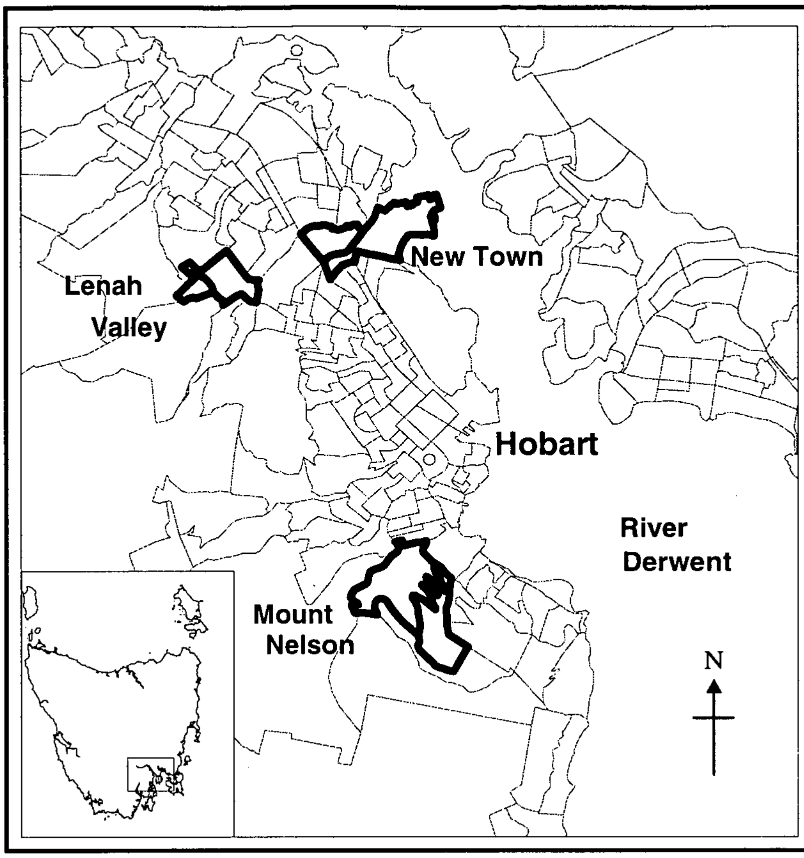
The stratified sampling technique employed to select the sample area uses two variables, socio-economic status and dwelling type. Socio-economic status is used as a variable to ensure that households ranging from low to high income are proportionally represented in order to avoid sampling bias. Data on socio-economic status are available from the 1991 Australian Bureau Statistics census for both suburbs and collection districts within the Hobart municipality.

The second variable, dwelling type, is used because of its particular importance to this survey. The opportunities and constraints of different dwelling types are likely to affect the occupants' attitudes to home composting, a major concern of this survey. For instance, a household occupying a house with a garden would both have more space available and an incentive than a household would in a flat. These factors may influence the household's willingness to support large scale composting facilities. A further reason for using dwelling type as a variable is that medium to high density housing areas in the Hobart municipality tend to be concentrated in little clusters, stretching in a belt from Sandy Bay to New Town (Australian Bureau Statistics 1991). Such clusters could easily have caused an under representation, of dwellers of this type of households, in a spatially random sample.

5.2.2 THE SAMPLE AREAS

In selecting the sample areas, the Hobart Social Atlas (Australian Bureau Statistics 1991) was initially used to determine socio-economic status and dwelling type. Three suburbs (New Town, Lenah Valley and Mt. Nelson) were then chosen based on the stratifying variables. Mt. Nelson was selected as it had a high population of high-income households, while Lenah Valley had a high level of medium income households. However, since both these suburbs displayed a low ratio of medium to high density dwellings, New Town, a suburb with a high ratio of medium to high density dwellings and low socio-economic households, was also included. See Figure 5.1 for location of sample area.

Figure 5.1: Location of sample areas



The three suburbs include a total of 28 ABS collection districts. To make the survey manageable the sample areas were reduced to two ABS collection districts in each of the three suburbs. Selection of collection districts was again based upon the stratifying variables.

Table 5.1 and 5.2 indicate that the proportion of both separate dwellings and higher socio-economic status households in the sample area are slightly higher than those for the Hobart municipality as a whole, although the actual surveyed data shows a better correlation for dwelling type (Table 5.3) For detailed information on dwelling types see Appendix 5,6,7,8,9, and 10.

Table 5.1: Comparison of dwelling type between the sample area and the Hobart Municipality

	Medium To High Density		Separate Houses	
	Total	per cent	Total	per cent
Sample Area	437	28.9%	1,075	71.1%
Hobart municipality	6,055	32.2%	12,490	67.3%

(Source: 1991 ABS Census)

Table 5.2: Comparison of socio-economic status between the sample area and the Hobart Municipality

	Socio-Economic Status (Income)					
	Less than $25,000		$25,000 to $50,000		More than $50,000	
	Total	%	Total	%	Total	%
Sample Areas	224	28.7	306	39.2	250	32.0
Hobart municipality	3,086	32.1	3,750	39.0	2,777	28.9

(Source: 1991 ABS Census)

To ensure that the samples are representative of the community the surveyed data was compared with the 1991 Australian Bureau Statistics census data. Representation by dwelling type was selected as the variable for comparison. As can be seen in Table 5.3, the sample is highly representative.

Table 5.3: Comparison of dwelling types between surveyed data and the Hobart Municipality

Dwelling Type	Surveyed Data %	ABS 1991 Data for the Hobart municipality %
Medium to High Density	31.3	32.7
Separate Houses	68.7	67.3
Total	100	100

5.2.3 *Sample Selection*

The computer-based geographic information system (GIS), Mapinfo, was used to compile a list of all addresses in the sample area. The total of 1,368 addresses were then transferred into an Excel spreadsheet noting also whether the dwelling was on the left or right hand side of the street.

With time and resource constraints, it was not feasible for the author to carry out a large survey. Having considered the details needed in the survey and after consultation with staffs familiar with social surveys, (Wilde pers. comm. 1997; Kriwoken pers. comm. 1997), at the Department of Geography and Environmental Studies, it was decided to restrict the size of the overall sample size to 150 households, divided equally between the three sample areas.

A systematic sampling technique using a fixed interval, calculated by dividing the total number of addresses in each sample frame by the required sample size, was used to select the final sample. A random number table was used to select the 6th listed address in each area as the starting point. Even and odd street numbers (left and right side of street) were then sampled alternately. This ensured that addresses on one side of the street were not selected more often than the other side. When situations arose where there were no dwellings on the opposite side of the street, then the selection remained on the side of the street with dwellings.

5.2.4 NON-RESPONSE

Non-response is the term used to define the samples, which have been selected but cannot be included in the survey. Past studies have identified a number of reasons for non-response (de Vaus 1991). These include households not being contactable or unwilling to participate, people from non-English speaking background, and those due to being too old, invalid or sick to respond coherently to the questions. Non-response can reduce the sample size, thereby affecting the quality of the surveyed data. A number of strategies have been proposed to overcome non-response (Moser and Kalton 1972; Gardner 1976; de Vaus 1991), including returning at different times of the day and the use of interpreters for respondents experiencing difficulties with language. The strategy adopted here was to survey the next address on the left of the non-respondent's with the same dwelling type.

5.3 SELECTION OF THE SURVEY METHOD

The three main methods employed to administer questionnaires in social surveys are personal interviews, telephone interviews and mail surveys. There has been considerable debate about the effectiveness of the three methods in the literature (Fowler 1984;

Mitchell and Carson 1989; de Vaus 1991). A method generally used to measure the effectiveness of a survey method is the rate of response (de Vaus 1991). There is a general agreement that the following parameters have an impact on the effectiveness on all three methods: availability of information; availability of resources and funding; the time frame; interviewer's skills; respondent's education level; and the design of the questionnaire.

The survey canvasses support for the concept of recycling organic waste as an alternative waste disposal method. Although the term "recycling" is commonly used for dry waste streams, it was not expected that many respondents would be familiar with organic waste recycling. It was assumed that respondents familiar with the topic would have a degree of interest and thus motivation to participate in the survey (de Vaus 1991). In order to avoid survey bias, it was considered that the capacity to motivate respondents to participate would be crucial, irrespective of the chosen method.

Telephone interview and the mail survey methods were considered initially, because of their low cost. Telephone interviews are recognised for a high response rate with a minimum amount of time and expense (Mitchell and Carson 1989; de Vaus 1991). The direct interaction between the interviewer and the respondent also offered benefits in terms of clarifying unclear responses, queries or misunderstandings. However, the difficulty in obtaining the telephone numbers of the sample population, conveying detailed information in relation to multiple answer questions over the telephone, and arranging convenient appointments with all the respondents, made the telephone interviewing unsuitable for this survey. The mail survey offered benefits in terms of savings in time however, since mail surveys are generally noted for their low response plus often bias in respondents (de Vaus 1991), it was decided that this technique would be unsuitable for this survey. The unfamiliarity of the survey topic may not motivate the respondents to respond.

The face to face personal interview technique was chosen for this survey as it offered the best method to achieve a high response rate. Although the response rate with personal interviews is generally high (de Vaus 1991), some non-response is nevertheless likely to occur. However, this method has an advantage because it gives greater control in managing non-response. The physical presence of an interviewer can entice an unmotivated or uninterested respondent to participate in the survey (Mitchell and Carson 1989). The interviewer in turn can convey complex ideas more readily, question unclear responses and clarify queries. With less educated or older respondents, the interviewer can pace the interview accordingly and repeat questions when respondents indicate puzzlement or uncertainty (Mitchell and Carson 1989). A further advantage of personal interviews is that data about the types of non-response can be obtained. The interviewer has the opportunity of recording observable information such as vacant or demolished dwellings, individuals being away from home or their refusal to participate. Such information can then be used to make the necessary adjustments during analysis to neutralise the effects of non-response bias (de Vaus 1991).

5.4 Method of Data Collection

Interviews were conducted in August 1996 over three days for each suburb and completed within nine days. Both weekdays and weekends were chosen so as to ensure households who work would not be excluded in the survey.

Various techniques ranging from observation to in-depth interviews, content analysis and questionnaires have been used for collecting data in social surveys (de Vaus 1991). The most commonly used technique in social surveys is the questionnaire which was chosen because it allowed questions to be systematically structured and the same set of questions to be applied to all the respondents. The questions in this survey were designed to measure attitudes and attributes of the respondents. Any differences in answers were taken to indicate differences between respondents and not as an indication of how the question was administered. See Appendix 11 for copy of the questionnaire.

5.4.1 Question Construction

Questions that are vague, ambiguous or leading are another source of bias in surveys, and in some instances, non-response. A number of guiding principles have been proposed to assist with constructing questions (Moser and Kalton 1972; de Vaus 1991). The process developed on the basis of these principles involved:

- identifying the concepts to be measured;
- recognising the kind of information required;
- determining which questions to ask; and

- determining how the questions are to be asked and worded.

The completed questions were pretested a number of times to sharpen concepts and eliminate wording that proved to be vague, ambiguous or leading.

5.4.1.1 RESPONSE FORMAT FOR QUESTIONS

The other aspect of question construction is the format by which the response is to be obtained. The two types of response format used in questionnaires are the closed or forced type questions and open-ended questions. There is extensive discussion of the benefits and limitations of both types of format in the literature (Moser and Kalton 1972; Fowler 1984; de Vaus 1991).

In the closed or forced type questions, a number of alternative answers are provided for the respondent to select one or more answers. The benefit of closed type questions is that the answers aid the respondent in making reference to the survey topic, which he/she may not be familiar with or hold an opinion on (Moser and Kalton 1972). It also motivates and makes the survey more enjoyable for the respondent, as the questions can be answered quickly. In addition, this approach assists respondents who are less articulate in expressing their opinions (de Vaus 1991). On the other hand, alternative answers in a poorly constructed questionnaire have the potential to restrict respondents from expressing their own views on the topic in question. The respondent is confined to the fixed answers that have been based on the views and opinions of the researcher. This could not only bias the data but also prevent the researcher from obtaining original data directly from the respondent.

The open-ended questions offer the opportunity for the respondent to formulate his/her own answer to the questions. The interviewer's role is to record the answers. The benefit of open-ended questions is that it allows the respondent to think through the topic, and express his/her opinion. Furthermore it allows the researcher to obtain accurate as well as unanticipated answers (Fowler 1984). However, limitations arise in situations where respondents find the questions too difficult or do not feel motivated or confident to state his/her opinion. Under such circumstances, probing by the interviewer to assist the respondent can result in unintended bias of the data, which may be introduced when the interviewer places his/her own interpretation to the questions or offers answers (de Vaus 1991).

The closed question format was selected as the main type of response format as the multi-choice answers would be helpful for those respondents unfamiliar with the survey topic. It was envisioned that by presenting multiple answers, the respondent would not be daunted by the task of producing an answer. Although multi-choice answers have the potential to bias originality in the data, this was not seen to be an overriding issue, as most respondents were not expected to have thought through the topic in question. However, measures were taken to deal with answers that differed from the alternative answers provided in the questionnaire. The author included options in the alternative answers with the choice of "other", "don't know", "undecided" or "not sure". Space in the questionnaire was allocated for the interviewer to record any unanticipated answers. By making the closed response format flexible, it provided the respondent with the option to choose on how they want to respond.

Closed type questions have considerable practical value in terms of coding answers which greatly assists during the interview, simplified data entry and analysis (de Vaus 1991). The answers to open-ended questions need to be interpreted and categorised by a skilled person prior to statistical analysis. This ensures the quality of the surveyed data is maintained.

5.4.2 LAYOUT OF QUESTIONNAIRE

The layout of a questionnaire has the potential to cause both non-response and bias the survey data. Questionnaires that do not provide sufficient space for respondent's views, limit options in closed formatted questions, or generally lack a good logical flow, have the potential to discourage respondents (de Vaus 1991). With personal interviews there is also a need for clearly printed instructions for the interviewer to read, edit and code smoothly (Moser and Kalton 1972). The following two aspects were considered in designing the questionnaire for this survey.

- Firstly it was to be practical for the interviewer. This included: contingency routes to direct the interviewer to the relevant question; font size and style that distinguished headings and questions; separate sections distinguished by the clearly identifiable section numbers; and, visual aids, one with interviewer's introduction and concluding statements (see Appendix 12) and another, listing multiple answers for questions with large number of alternative answers (see Appendix 13).

- Secondly, the questionnaire was designed to have a logical flow. The initial questions were directed within the experience of the respondent (i.e. respondent's regular waste disposal practices), followed by questions which looked at alternative waste disposal methods. The more abstract questions, which canvassed potential solutions for waste disposal, were asked towards the end of the questionnaire.

5.5 PRETESTING OF QUESTIONNAIRE

The questionnaire was pretested informally and formally to ensure that it met the objectives set by the author. The informal pretest was carried out with friends, colleagues and staff at the University of Tasmania during the construction of the questionnaire. The purpose of the informal pretest was to check on the clarity of questions, the adequacy of the questions, the adequacy of the alternative answers, and the efficiency of the layout of the questionnaire. During these interviews, the author changed and modified questions that respondents found difficult to understand and needed clarification with. The respondents were quizzed about the difficulties they experienced and asked to suggest ways to improve the questions. Answers most frequently given by respondents, as well as answers that had not been anticipated by the author or included in the precoded answers, were noted. Respondents were also asked to comment on the layout of the questionnaire. Suggestions offered by the respondents were considered in detail, and where appropriate, used to improve the questionnaire.

It has been suggested that pretesting should be conducted on a group of people which resembles the actual sample that is to be surveyed (de Vaus 1991), so the upgraded questionnaire was then formally pretested on a randomly selected sample of 30 households. The stratifying variables (i.e., dwelling type and socio-economic status), used in selecting the main sample, were utilised to select the sample population for the pretest. The identification of the socio-economic status of households in this instance was based on the author's observation of the quality of dwelling. Of the 30 samples selected, 20 households were separate houses and 10 were medium to high density dwellings.

The purpose for this pretest was to ensure that the questionnaire was adequate and to test the coding responses in the statistical analysis database. Factors that were taken note of were: questions that made respondents uncomfortable; questions that were misinterpreted by the respondents; and questions that the interviewer found difficult to read. The necessary adjustments were made to these questions. The results from the pretest survey were tested in the statistical database to ensure that there were no problems with the coding of the questions.

5.6 PROCESSING THE SURVEY DATA

Two computer-based databases were utilised in processing the survey data. The first database, Microsoft Access, was used to compile and store the data from the questionnaire. The data were then down loaded into the second database, Statistical Package for Social Sciences (SPSS). In SPSS the data were analysed and used to develop tables and graphs.

5.7 EVALUATION OF THE SURVEY

5.7.1 SUCCESS RATE

Given the length of the questionnaire (8 pages), it was surprising that most interviews took only between 10 to 15 minutes, although in some cases, especially where respondents were old or/and of non-English speaking background, a few interviews took up to 30 minutes. Of the 150 samples chosen for the survey, 30 (20 per cent) of the households had to be replaced (see Table 5...). Respondents who due to their old age or poor health, were not logically consistent in their response, were excluded. Also excluded were respondents from non-English speaking background who, due to their limited ability to communicate in English, could not respond to the interview questions. The 'refuse to participate' category included those respondents who chose not to participate in the survey, as well as those who claimed to be busy at the time of the interview. The 'not home' category had the largest number of non-respondents. This is to be expected as no prior appointments were made with the respondents for the

interview. Non-respondents were replaced as discussed in section 5.2.4. In most instances replacements were the selected sample's immediate neighbour, however in some instances, two to three dwellings had to be approached before a respondent could be found.

Table 5.4: Non-respondents and reasons for replacements

Category	Number
Too Old	3
Non-English Speaking	5
Refused to Participate	7
Not Home	12
Vacant Homes	3
Total	30

5.8 CHAPTER SUMMARY

This Chapter examined the theoretical implications of carrying out a social survey and discussed the practical implementation of the methodology for this survey. The results of this survey will be discussed in the following Chapter.

6. RESULTS OF THE SURVEY

6.1 INTRODUCTION

The public survey carried out for the thesis aimed to examine the recycling experiences and practices of the Hobart community. Particular attention was paid to the way the community responded to the organic waste recycling strategies advocated by the Hobart City Council. Another aim of the survey was to critically review the Council's effort in encouraging households to recycle organic waste. In addition, since community support will ultimately be necessary for the viable operation of large scale composting facilities, the level of community support available was examined.

Data obtained from the public survey were analysed and presented in this Chapter. The data are presented in the same order as set out in the questionnaire, beginning with: examining the participation rate for current recycling programs for low to moderate biodegradable waste; present disposal practices for domestic organic waste (i.e., kitchen/food waste, green waste and paper waste); determining the effectiveness of the Hobart City Council's promotional and educational strategies; incentive to encourage households to take up home composting; and characteristics of households which carry out home composting; and community support for centralised large scale composting schemes.

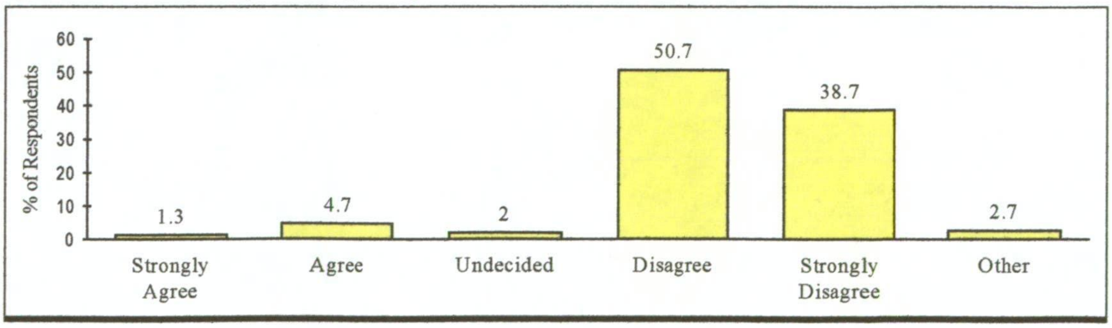
6.2 Community Participation in the Current Recycling Program for Low to Moderate Biodegradable Materials

To determine the level of importance the community places on recycling schemes, the survey examined the number of households presently participating in the current kerbside recycling program for the recovery of dry materials. The response was overwhelmingly favourable, with the survey findings indicating a 92 per cent participation rate.

The small group of households (8 per cent) who did not participate cited reasons which varied from not being in possession of a recycling bin or having had their bin stolen to 'could not be bothered to separate and place recyclables into the recycling bin'. Households who claimed not to be in possession of a bin also indicated that they did not know how to obtain a replacement bin, while others felt that the cost charged for replacement bins should be waived, as it was not their fault that the bins had been stolen.

The source separated kerbside collection service, which is currently promoted as the most effective method for collecting domestic recyclable materials, was examined with regard to its success in motivating households to participate in the recycling scheme. There is some concern that the program might impose an inconvenience on households with the task of separating recyclables from waste (Reschovsky and Stone 1994). Households were queried how they felt about the task, and judging by the response (89.4 per cent), inconvenience is clearly not a factor with most people (Figure 6.1).

Figure 6.1: Was separating recyclable materials from waste inconvenient



6.3 PRESENT DISPOSAL PRACTICES FOR DOMESTIC ORGANIC WASTE

The Hobart City Council encourages households to compost kitchen and green waste at home; and recycle green waste and paper, through the recycling programs it operates. In this section an attempt is made to examine the present methods employed by households to deal with their kitchen/food waste, paper waste and garden waste.

6.3.1 DOMESTIC KITCHEN/FOOD WASTE

Households were surveyed on how they dealt with their kitchen/food waste, which includes vegetable scraps, meat and bone scraps, left over food, egg shells, tea leaves and coffee grounds. The various methods used by households to dispose of each category of kitchen/food waste are displayed in Table 6.1.

Table 6.1: Methods employed by respondents to dispose of household organic waste

Disposal of	Discard in Garbage Bin	Take to Tip	Bury	Compost	Other	Total
Vegetable Scraps	**53.3**	**1.3**	**4.0**	**33.3**	**8.0**	**100**
Meat and Bone Scraps	**62.7**	**0.7**	**0.7**	**2.0**	**32.2**	**100**
Left Over Food Scraps	**51.3**	**0.7**	**2.7**	**26.7**	**18.7**	**100**
Egg Shells	**62.7**	**0.7**	**1.3**	**3.4**	**26.2**	**100**
Tea Leaves and Coffee	**55.3**	**0.7**	**2.7**	**23.3**	**16.7**	**100**
Other: includes feeding pets and animals, give away to neighbours who compost and flushing down toilets and sinks						

6.3.2 HOUSEHOLD GARDEN WASTE

Household garden waste examined in the survey includes garden weeds, lawn clippings, raked leaves, bush and branch trimmings and general garden waste. The various methods used by households to dispose of each category of garden waste are displayed in Table 6.2.

Table 6.2: Methods employed to dispose of garden waste

Disposal of	In Garbage Bin	Take to Tip	Recycling Depot	Burn	Bury	Compost	Other	Total
Garden Weeds	**6.6**	**18.2**	**7.4**	**7.4**	**4.1**	**48.8**	**7.4**	**100**
Lawn Clippings	**4.1**	**13.2**	**7.4**	**4.1**	**5.0**	**49.6**	**16.5**	**100**
Raked Leaves	**4.1**	**13.3**	**7.4**	**4.1**	**5.0**	**50.4**	**15.7**	**100**
Bush/Branch Trimmings	**3.3**	**39.7**	**19.8**	**18.2**	**0**	**8.3**	**10.7**	**100**
General Garden Waste	**4.1**	**37.2**	**18.2**	**26.4**	**0**	**2.5**	**11.6**	**100**
Note: 19.3 per cent of households did not have a garden								
Other: includes the gardener or contractor removing the waste								

6.3.3 Paper Waste

Due to the wide variety of paper waste, this survey focused on how households dealt with newspaper, white paper, paper packaging and magazines. The various methods used by households to dispose of each category of paper waste are displayed in Table 6.3.

Table 6.3: Methods employed to dispose of paper waste

Disposal of	In Garbage Bin	Take to Tip	Recycling Bin	Recycling Depot	Burn	Compost	Other	Total
News-paper	**17.3**	**2.7**	**38.0**	**4.7**	**18.0**	**1.3**	**18.0**	**100**
White Paper	**52.0**	**1.3**	**10.0**	**4.7**	**24.7**	**0**	**7.3**	**100**
Paper Packaging	**38.0**	**6.0**	**12.0**	**8.0**	**22.7**	**0**	**13.3**	**100**
Magazines	**28.2**	**1.3**	**14.8**	**4.7**	**10.7**	**0**	**40.3**	**100**
Other: includes giving to family, friends or donating to charity organisations								

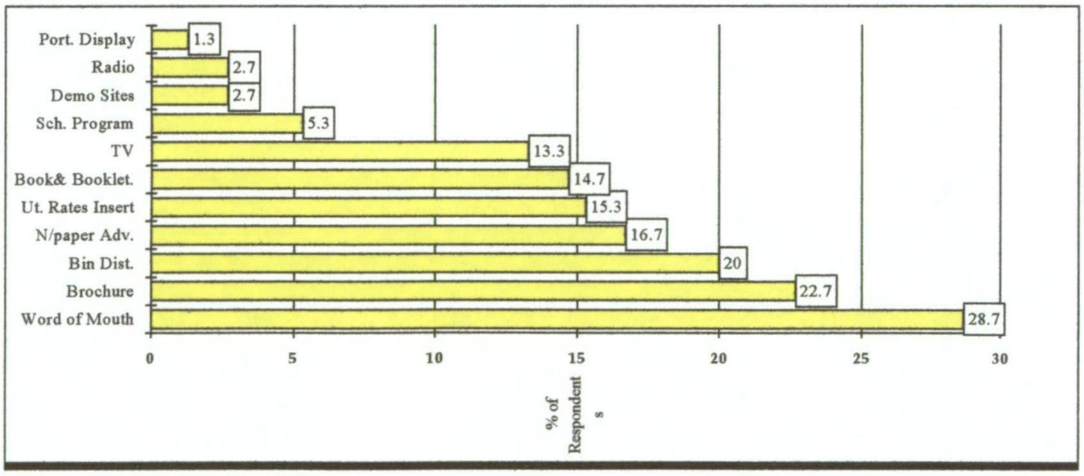
6.4 Effectiveness of Hobart City Council's Promotional and Educational Programs

The success of the home composting strategy relies on the promotional program reaching a large audience to inform and stimulate interest in home composting (Johnson 1995). An indication of the level of attention paid by householders to Hobart City Council's home composting program can be derived from examining the households' access to information and their assessment of the adequacy of the information.

Although the Hobart City Council uses a number of mediums to promote its home composting program, almost half of the households (41.3 per cent) had not accessed this program. This points to a problem with the effectiveness of the Council's strategies to reach a wide audience.

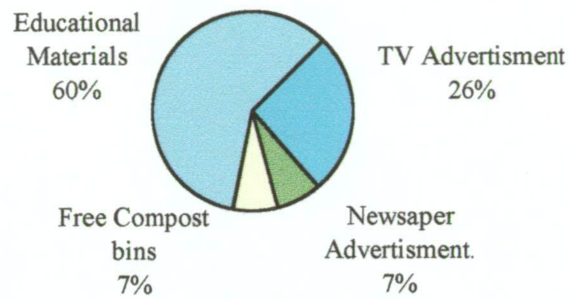
Nonetheless, the program was found to have reached a significant proportion of the community (58.7 per cent), with a number of households indicating that they accessed the Hobart City Council's home composting program through more than one medium. The relative effectiveness of the various educational media is indicated in Figure 6.2.

Figure 6.2: Sources through which households obtained information about home composting



Only one-third of the households (36.2 per cent) thought that the educational material was satisfactory. A quarter of the households (24.6 per cent) indicated that they needed more information, while more than one-third (39.1 per cent) were undecided on this matter. Almost two-thirds expressed the need for more educational materials, while a third suggested advertising on television as a more accessible medium of information (Figure 6.3).

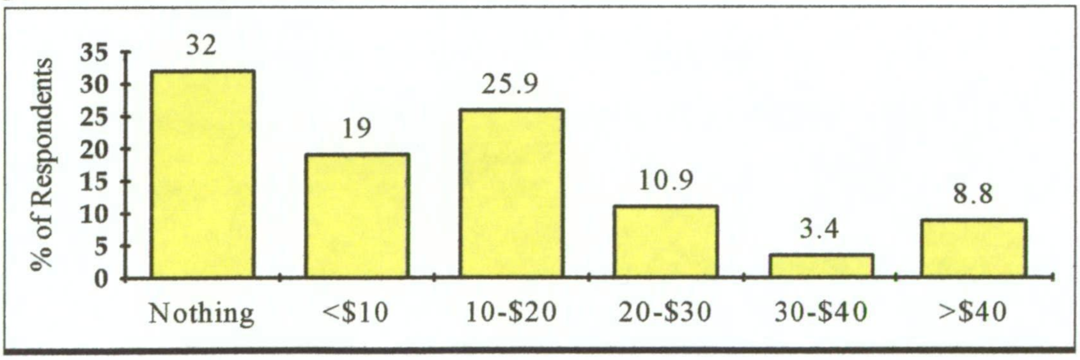
Figure 6.3: Householders' views on how to improve promotional programs



6.5 Incentives to Encourage Households to Take Up Home Composting

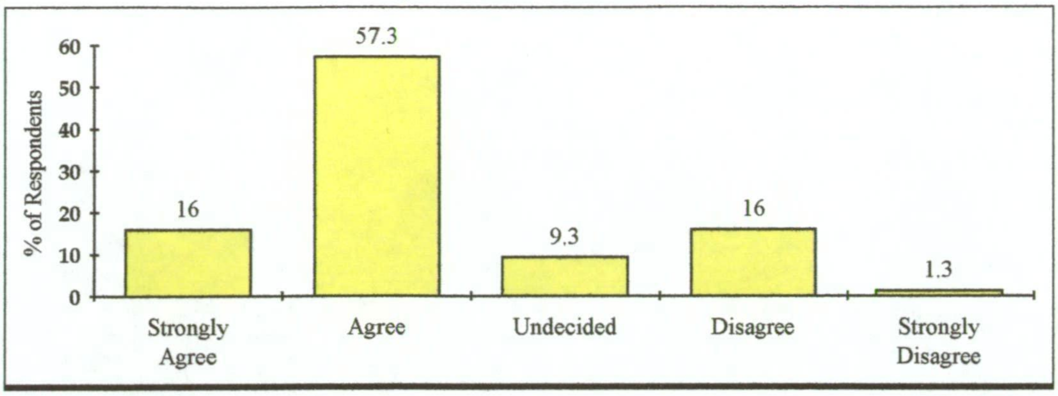
To examine the effectiveness of the Hobart City Council's existing compost bin subsidisation strategy a survey question was included to assess the willingness of households to pay for a compost bin should they be required to compost some organic waste at home. One-third of the households would refuse to pay anything, however the other two-thirds responded positively. The amounts households were willing to pay are displayed in Figure 6.4.

Figure 6.4: Willingness to pay for composting bin



Although two-thirds of the community were prepared to pay for a compost bin, the majority was of the opinion that compost bins should be subsidised (see Figure 6.5). 38 per cent thought that the Council should pay for the subsidy while 56.9 per cent thought that both the Council and the state government should bear the cost.

Figure 6.5: Subsidisation of compost bins



6.6 CHARACTERISTICS OF HOUSEHOLDS WHICH CARRY OUT HOME COMPOSTING

The effectiveness of the Hobart City Council's home composting strategy was assessed by examining: the interest stimulated in the community to carry out the practice; the ability of home composting to divert organic waste from the waste stream; and the level of attention paid to the home composting techniques.

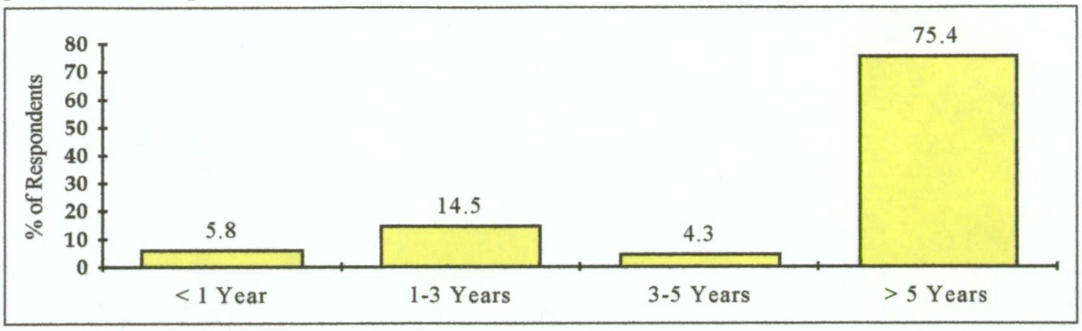
6.6.1 PROFILE OF THE HOME COMPOSTERS AND THEIR OPERATIONS

The survey found that slightly less than half of all households (46.7 per cent) compost organic material at home, with the majority of these (94.3 per cent) residing in separate houses. The non-composters (53.3 per cent) make up the majority, with 91.5 per cent residing in medium to high density dwellings. The difference between households in the two dwelling types is to be expected, as medium to high density dwellings generally do not have sufficient space for composting operations.

Home composting is generally carried out in compost bins or home made devices such as compost heaps or boxes, with compost bins (53.8 per cent) being found to be slightly more popular than compost heaps (46.2 per cent). The majority of households (71.4 per cent) have one bin, while a small proportion had two (16.7 per cent) or three (11.9 per cent) bins. One-third of households (31 per cent) had obtained their bin through the Council's subsidised bin program, while two-thirds (69 per cent) had bought their bins at hardware stores. A number of households who purchased their bins through hardware outlets commented that they were unaware of the Council's subsidised compost bin program.

About one-quarter of the composters established their composting operations at about the same time or after the Hobart City Council began promoting their program in 1992 (Figure 6.6), however, the majority (75.4 per cent) have been composting for more than 5 years.

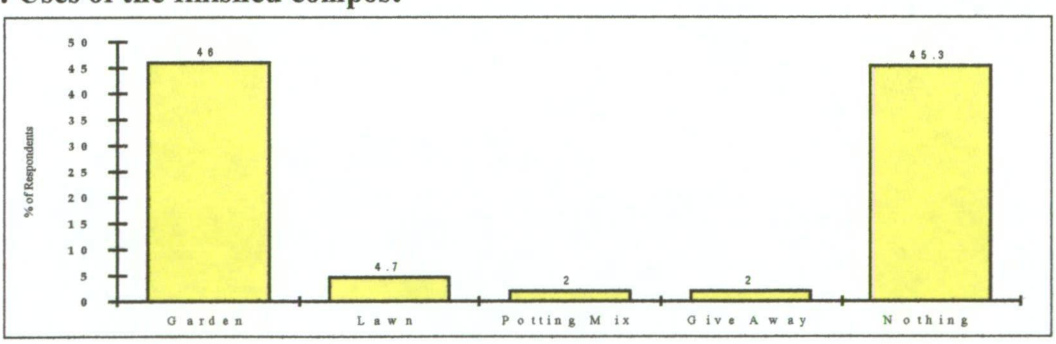
Figure 6.6: Length of time households have been composting



6.6.2 The Potential to Divert Domestic Waste From Landfills Through Home Composting

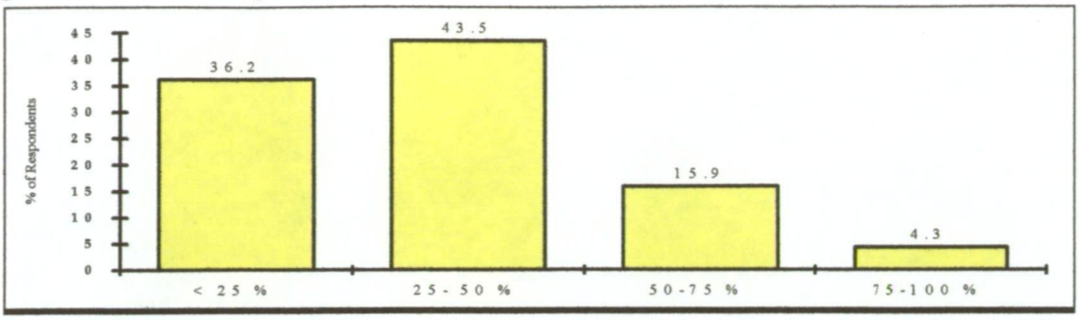
Compost produced from organic waste can be utilised as a plant growing medium in a variety of applications, a factor stressed in the promotional strategy to encourage home composting. A significant proportion of the home composters use their compost in their gardens and a small proportion, on lawns and potting mixes (Figure 6.7).

6.7: Uses of the finished compost



The survey findings indicate that home composting has a significant potential to divert organic matter from the waste stream. Almost half of the composters were found to compost between 25 to 50 per cent, by volume, of their weekly waste while about one-fifth of households were composting more than 50 per cent of their weekly waste (Figure 6.8).

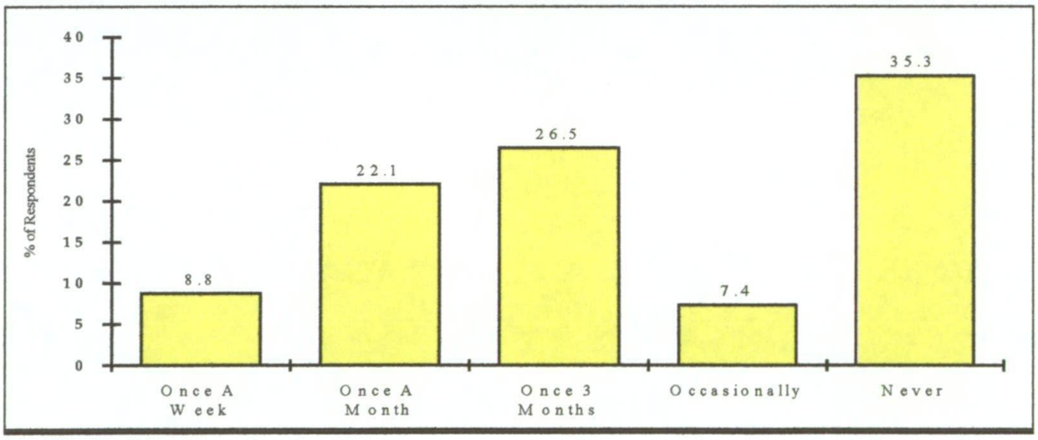
Figure 6.8: Percentage of waste reduced from weekly garbage bins



6.6.3 HOUSEHOLDS' AWARENESS OF PROPER COMPOSTING TECHNIQUES

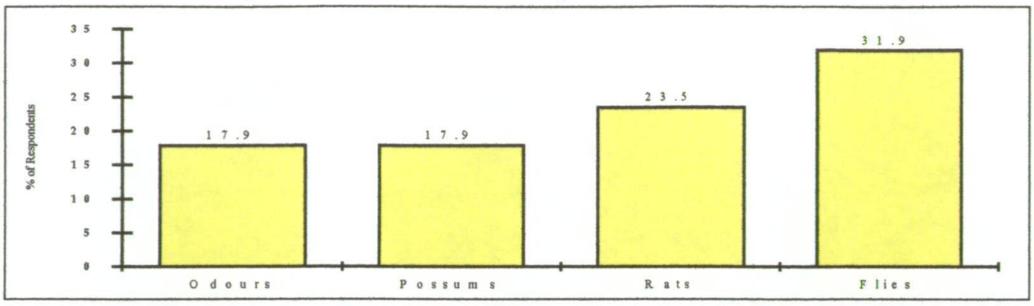
Studies have shown that enhanced decomposition can be promoted in home composting units by maintaining proper aeration and moisture levels in the compost pile (Strauch et al. 1995). Failure to do so can result in the production of a poor quality compost as well as problems such as odours and vermin attraction. The survey findings indicate that the majority of households aerate their compost at intervals ranging from weekly to once in 3 months (Figure 6.9). However, significant proportions of households (45.7 per cent) aerate their compost rarely, if at all.

Figure 6.9: Rate at which households aerate their compost



The survey found that more than half of the households (53.6 per cent) do not experience any problems with their composting operation. The remainder mentioned a number of concerns, particularly flies but also followed by pests (possums and rats) and odours (Figure 6.10). When asked if they regarded these issues to be of concern 97.2 per cent thought that these disadvantages were not serious enough to deter them from composting.

Figure 6.10: Issues experienced in home composting

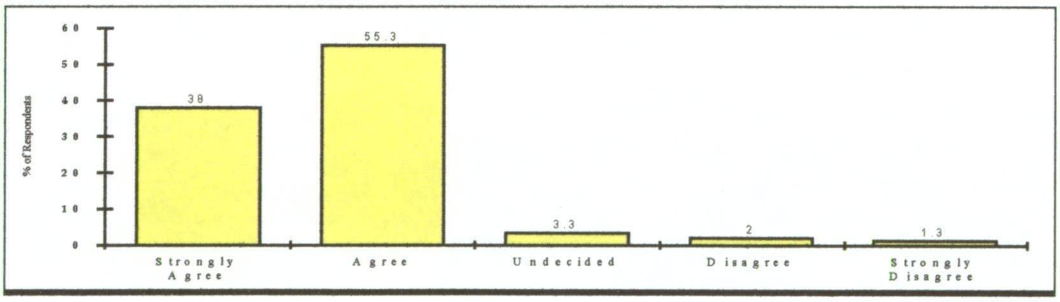


6.7 COMMUNITY SUPPORT FOR CENTRALISED LARGE SCALE ORGANIC COMPOSTING SCHEMES

The Hobart City Council currently operates a mulching service at its disposal site. It operates a chipper/shredder to recycle green waste into mulch, which is used by the Council as well as offered for sale to the public. The survey found that almost one-third (29.3 per cent) of households utilise this service for either disposing of their garden waste or by purchasing mulch for their gardens.

The concept of the Council operating a centralised large scale composting facility to convert organic waste into compost was canvassed by the survey to examine the level of support that could be expected from the community. The results are displayed in Figure 6.11.

Figure 6.11: Support for large scale organic waste composting

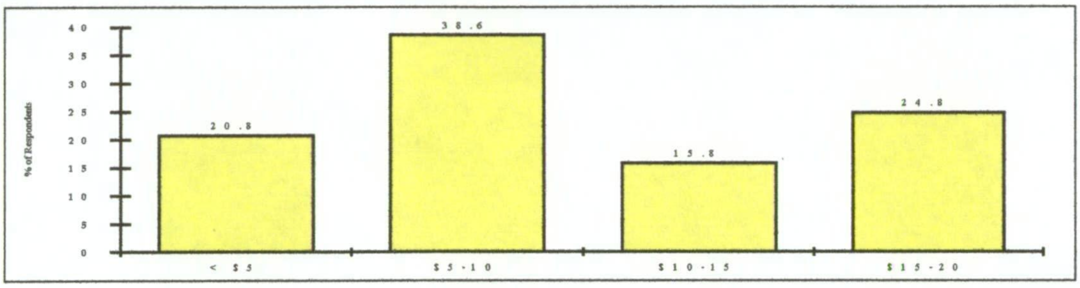


Households were queried if they would participate in a source separated organic waste collection program service to ensure the successful operation of large scale composting schemes. The survey indicates that community participation in a source separated organic waste collection program can be expected to be high. The majority of households (87.3 per cent) expressed their willingness to separately place organic waste in a special recycling bin. Of those households which did not want to participate in the program (12.7 per cent), 5.3 per cent thought that it would be an inconvenience, while

6.0 per cent wanted to use the organics for their own home composting operations and 1.3 per cent were concerned about health issues. There was also strong support to the idea of a separate green waste collection service, with 77.3 per cent indicating that they would participate in the program.

Households were queried on their willingness to pay for the establishment of large scale composting facilities. More than two-thirds of households (69.1 per cent) showed their willingness to pay for its establishment (Figure 6.12). More than half would be prepared to pay between \$1 and \$10, while just under half the households indicated between \$10 and \$20.

Figure 6.12: Willingness to pay for the establishment of large scale composting schemes



6.8 Chapter Summary

This Chapter presented the results from the survey. The following Chapter analyses the survey results and reviews the Hobart City Council's current home composting program, and assesses the viability of the Council operating a large scale composting program.

7. Discussion and Conclusion

Waste management in Tasmania has progressed significantly since the 1970s. Councils now have the benefit of a state waste policy for guidance and direction. In recent years, councils in Tasmania have begun taking measures to implement the principle strategies of the TSWMP (1994) into their local waste management plans and practices. The operation of resource recovery programs is now common practice for municipalities, which has resulted in improved waste disposal practices in many parts of the state.

However, the main problems confronting waste management in Tasmania are yet to be resolved. This includes dealing with the increasing rate of waste being generated, meeting the rising cost of waste disposal and finding solutions for the 50 per cent of landfills approaching their expiry date. Diverting the large proportion of organic waste from the waste stream has the potential to resolve the problems confronting waste management in the state. This Chapter will discuss the effectiveness of current strategies employed to deal with organic waste in the Hobart municipality, with the aim of examining the issues and identifying solutions, to produce a better outcome.

7.1 Current Recycling Practices for Low to Moderate Biodegradable Waste

There appears to be a high level of support for current recycling programs in the Hobart community. This is obvious from the survey results, which shows a high participation rate (92 per cent) in the current kerbside collection program, which is aimed at recovering low to moderate biodegradable waste from the waste stream. This strong support for recycling is in line with the findings of other surveys evaluating community support for recycling programs (Clouser 1989; Dowson 1991). The survey found that the majority of households (89.4 per cent) did not consider the task of separating recyclable materials and placing them into a separate bin as an inconvenience. The findings of this survey reflect those of an earlier study carried out in the municipality of Glenorchy (Clouser 1989), which found that a significant proportion of households (83.9 per cent) would be willing to separate recyclables from waste, if this would ensure the feasibility of the recycling program.

However, the same level of support does not apply to the home composting program. The survey found that less than half of the Hobart community (46.7 per cent) carries out home composting.

7.2 Disposal Method for Kitchen/Food Waste, Green Waste and Paper Waste

Organic waste makes up the largest proportion of the waste stream in most parts of the Western world. Waste composition studies carried out in Tasmania established that putrescible and paper waste make up almost two-thirds of the domestic waste stream (Dowson 1991).

The survey found that the choices of organic waste disposal methods by the Hobart community varies with the type of waste and the convenience to recycle it. Kitchen/food wastes that are composted include vegetable scraps (33.3 per cent), left over food scraps (26.7 per cent), tea leaves and coffee grains (23.3 per cent). The majority of the households however continue to discard all types of kitchen/food waste into the waste stream. This could explain for the large proportion of putrescible waste entering the waste stream, as found by Dowson's (1991) study.

The organic fractions selected by households for composting are mostly those that are readily decomposable but not prone to causing odours, (i.e., vegetable scraps, left over food, tea leaves and coffee grounds). Waste such as meat and bone scraps and left over food is mostly fed to pets or animals. Others commented that they dug egg shells, tea leaves and coffee grounds, into their garden soil. Many people also admitted to flushing their tea leaves and coffee grounds down toilets or the kitchen sink.

Garden waste is diverted from the waste stream to a much larger extent. When a differentiation is made between types of garden waste, composting appears to be the most common method of disposal for the more readily degradable and manageable garden wastes such as garden weeds(48.8 per cent), lawn clippings (49.6 per cent), and raked leaves (50.4 per cent). It is apparent that bulkier and heavier garden wastes such as bush and branch trimmings (39.7 per cent) and general garden wastes (37.2 per cent), are mostly carted away and discarded or recycled at the tip. The inconvenience of preprocessing the bulkier and heavier garden wastes could explain for the high rate of households opting to discard the waste into the tip face. A smaller proportion of households recycle their bush and branch trimming (19.8 per cent) and general garden waste (18.2 per cent) into mulch at the Hobart City Council's recycling depot. Nonetheless, a large number of households were found to still discard all the types of garden wastes into landfill.

A cause for the high rate of green waste entering landfills could be associated with the limitation of the Hobart City Council's mulching program to deal with all types of garden waste. For instance, not all green wastes are suitable for conversion to mulch. Noxious weeds and invasive plants are unsuitable, as there is the potential to spread their seeds with the mulch. Currently these green wastes are sorted and diverted to landfills.

Another limitation of this program is the lack of convenience for households to recycle their green waste. Under the current program, households will have to cart their green waste to the recycling depot for it to be mulched. This is not expected to be a problem when a substantial amount of green waste is of concern as households would either cart the waste or have private contractors cart the waste to the recycling depot. However, it's the smaller amounts of green waste that raises the issue of convenience. For instance, there is a greater likelihood that households would place small amounts of green waste into garbage bags and discard it into the waste stream. It could also be expected that households, who cart their waste to the tip, would discard small amount of green waste along with their discarded waste into the tip face.

Paper waste poses an interesting issue. There is a generally held public perception that paper is widely recycled. In Tasmania, although the recovery of paper waste has been occurring for some time, it still makes up the second largest amount of organic waste entering landfills (Dowson 1991). A number of factors could explain the high proportion of paper waste entering landfills. Firstly, recovery of paper waste is restricted to newspapers, white paper, paper packaging and magazines. Thus all other types of paper waste not included in the recovery scheme, such as fast food packaging, gift wrapping paper, tissues, napkins, advertising material and merchandise wrapping paper, are inevitably destined to landfills.

Secondly, there are no consistent management plans for the recovery of the paper wastes. For example, the Hobart City Council collects newspapers and magazines through the kerbside collection program, while paper packaging is only collected at its recycling depot. White paper, on the other hand is only collected from the industrial waste stream but not the domestic waste stream, although the Council is currently in the process of trialing the collection of white paper in its kerbside collection program (Clarke pers. comm. 1997).

A further reason for paper waste entering the waste stream is associated with the unstable markets caused by a surplus of recycled paper in the global markets (Fagg 1990). In Tasmania, paper collection was temporarily dropped from many recovery programs in the early 1990s. An over supply of recycled paper on the world market saw prices fall to such levels that it was financially unviable for resource recovers to collect, process and transport the recycled paper (Mitchell pers. comm. 1996).

This survey found that a significant proportion of paper waste was diverted from the waste stream. Much of the newspapers were recycled (38 per cent) while a high proportion of magazines were reused (40.3 per cent). Newspapers were mostly recycled through the kerbside recycling collection service. Magazines, on the other hand, were mostly reused either by swapping or donating to a charity organisation. However, discarding into the garbage bin is still the most popular disposal method for white paper (52 per cent), magazines (28.2 per cent), and paper packaging (38 per cent). Burning and the 'other' category are the next most common disposal methods. Most households indicated the 'other' category to mean reuse. Burning is a common disposal method for white paper (24.7 per cent) and paper packaging (22.7 per cent). A significant proportion of households stated that they burnt the waste in their fireplaces or incinerators. Smoke emissions from incinerator fires, which are known to cause social as well as environmental problems, could be severely reduced if an efficient recovery program existed.

The 38 per cent participation rate for newspaper recycling which was found in this survey is higher than the 11 per cent found in Clouser's (1989). A possible explanation for this difference is that at the time of Clouser's study, there was no formal kerbside recycling collection program, and respondents had to take the trouble to separate and deliver the paper waste to a recycling centre. The increase in the recycling rate identified in this study is therefore thought to be associated with the greater convenience offered by the Hobart City Council's kerbside collection service.

The poor rate of recovery for paper packing on the other hand, can be associated with the inconvenience involved in recycling this waste (i.e., the need to separate and cart the waste to the recycling depot). In most instances household paper packaging waste consists of cereals boxes or frozen food boxes in quantities too small to justify carting to a recycling depot. The low recovery rate for white paper can be directly linked to the lack of a recovery program from the domestic waste stream. Lacking the option to recycle white paper can also explain for the high rate of households burning or discarding the waste into the waste stream.

Overall, it can be concluded that convenience is the crucial factor that determines a household's choice of either recycling or discarding organic waste into the waste stream. The lack in convenience to recycle could be associated to households currently discarding much of the domestic organic waste into the waste stream. It appears that households could be persuaded to recycle most of their organic waste through a more efficient and consistent recovery plan. The Hobart City Council's current kerbside collection service for low to moderate degradable waste is a good example of convenience for households to recycle. The Council would now need to examine ways to increase convenience for households to recycle the moderate to high biodegradable waste.

7.3 Home Composting

Home composting is an old practice which people have carried out in their backyards for ages to improve the fertility of their garden soils. The home composting strategy is an attempt to co-ordinate and promote the practice on a wider scale, as a means to divert domestic organic waste from entering the waste stream. The Hobart City Council had been promoting its home composting strategy since 1992. The survey however found that of the 46 per cent of the Hobart community who composted some organics at home, 75 per percent of the home composters have had their operations long before the Hobart City Council began promoting its home composting program. Many elderly householders commented that they have been composting for 30-40 years with some claiming to have started when they were very young. This clearly indicates that there already is an established core group of composters in the community. It also raises concerns with regards to the effectiveness of the Hobart City Council's home composting program to motivate households to take up the practice.

Half of the home composters used their home produced compost in their gardens. However, it is interesting to note that the other half did not have any subsequent use for the compost but just left it where it was composted. A number of these households commented that this did not concern them but that the main advantage was that their waste volume was reduced. Clearly, the perceived benefits of the compost were not the main motivation for their participation.

This survey found that the majority of home composters (43.5 per cent), in the Hobart municipality were diverting between 25 and 50 per cent of their weekly waste, while 36.2 per cent were diverting less than 25 per cent of their weekly waste. A fifth of the households were diverting greater than 50 per cent of their weekly waste. This indicates that there is the potential for a statewide home composting program to divert a significant proportion of domestic organic waste entering the waste stream in the state.

Proper composting techniques, such as aerating (or turning) the compost, is essential in home composting operations. This will not only improve decomposition but also ensure the safe use of the finished compost (from pathogens), and, prevent problems such as odours and flies, during composting. The survey found that majority of the composters aerate their compost at intervals, ranging from weekly to once in 3 months, however, it is of concern that a significant proportion of the composters (45.7 per cent), rarely if at all, aerated their compost. This could explain for the 43.6 per cent of households that experienced problems with flies, rats, possums and odours, with their composting operations. The majority of these households did not regard it to be a serious issue, however, the wider implication on public health does warrant concern.

7.4 LARGE SCALE COMPOSTING

Large scale composting is widely promoted as the most effective means of dealing with the organic fraction of municipal solid waste. Large scale composting is gradually gaining acceptance with the number of facilities increasing both in the US and the EU. Trials are currently being carried out by a number of the mainland states in Australia. The TSWMP (1994) encourages the development of large scale composting facilities within the framework of the regional waste management centres, so as to deal with the high cost of such operations utilising the economies of scale. There are strong merits in the establishment of centralised composting facilities. The most obvious lies in the capacity to deal with the largest proportion of municipal solid waste.

Another significant factor in favour of large scale composting is its ability to complement the home composting strategy. There are practical limitations to home composting in terms of the range of organic materials that can be utilised. Wastes, which needs processing, such as bulky materials, highly odorous and those with the potential to carry pathogens, such as meat and animal/pet faeces, are not suited to home composting operations. These wastes could be diverted safely and effectively dealt with in large scale composting facilities. In addition, such facilities would be well placed to deal with the organic waste from households which choose not to carry out home composting, and, that enters the waste stream through inappropriate waste management.

The Hobart City Council's present mulching service for green waste appears to have been well received by the community with up to one-third of households currently utilising the service. The majority of these households (77.3 per cent) indicated strong support for the Council to operate a separate garden waste collection service.

The survey indicates that there is strong community support for the concept of centralised composting, to deal with all types of domestic organic waste. An overwhelming majority of households (93.3 per cent) thought it was a good idea for the Hobart City Council to collect organic waste separately, compost and sell it. 87.3 per cent indicated preparedness to assist the program by participating in a source separated kerbside collection service. This is evidence that the community is aware of the issues associated with operating recycling schemes, and is prepared to accept responsibility, to ensure the success of the recycling scheme.

There is also clear evidence that the community would be prepared to match their support for centralised composting operations with their willingness to pay for the recycling scheme. 69.1 per cent indicated their willingness to pay for the recycling scheme and it is expected that an average increase of up to $10 in council rates will find support from the community. This is consistent with Dowson's (1991) domestic waste survey which found that up to 68 per cent of households would be willing to pay up to $10 a year to assist the operation of a recycling scheme. This reflects the strong support for resource conservation measures in the community.

7.4.1 FACTORS TO ~~BE~~ CONSIDER IN LARGE SCALE COMPOSTING

7.4.1.1 TECHNOLOGY

In pursuing large scale composting schemes, the Hobart City Council has a responsibility to ensure that the operations are conducted correctly and are economically viable. As discussed in Chapter two, composting of organic waste can be a highly complex and difficult process. The high technology composting systems automate most of the process control function, however, these systems have high establishment and maintenance costs, known to run into the millions of dollars. This would make it economically unviable for most municipalities in Tasmania to operate such facilities.

However, high technology facilities may not be required for the Hobart municipality. The Council needs to identify the most appropriate composting system based on the availability of suitable composting sites, the quality and nature of organic waste generated in the municipality and the economic constraints. If high technology is pursued, then it is essential that the Hobart City Council assess carefully the viability of the system. The development in composting technologies has resulted in the development of many expensive purpose-built high technology composting facilities. Although many of these facilities are effective in carrying out what they were designed for, their benefits are not always clearly evident. For instance, the emphasis placed on the benefits of enclosed composting systems, (i.e., the ability to carry out high rate composting in a short period [4 to 5 days]), disguises the fact that more time and management input will be needed before the compost can be safely used/sold. This may incur additional costs in terms of storage areas and aeration systems. The Council needs to take note of its inexperience in the area of composting and be cautious of unwarranted high technology facilities. Low technology facilities, such as the aerated static or windrow composting systems, have the capacity to be just as effective and, in most instances, for a fraction of the cost of high technology facilities.

The Hobart City Council could examine the suitability of old disposal sites or the current disposal site (McRobies Gully), and opt for the cheaper low technology aerated static pile or windrow composting systems. Both these systems not only cost little to establish and operate but also have the capacity to produce quality compost. It is, however, important to note that odours and flies can be a problem with the low technology facilities. It is therefore necessary to allow for a sufficient area of land as a buffer zone between composting sites and sensitive land uses when planning for such systems. Furthermore, since these types of composting systems are located outdoors and hence exposed to rainfall, it is essential that appropriate mechanisms be in place for trapping and collecting leachate. The trapped leachate could be recycled by using it to maintain moisture levels in the compost pile.

7.4.1.2 Commercialisation of Compost

The commercialisation of the compost produced from organic waste is an important aspect that is intrinsically aligned with its production. The earlier approaches to large scale composting, which saw the emphasis placed on the process of converting organic waste into compost, resulted in large amounts of compost being produced for which there were no markets (Glover 1995). To prevent such failures it is essential that the focus for composting be directly related to the end-use markets. For example, markets associated with the production of food, such as the agricultural and the horticultural sectors, will demand a high quality compost. To meet this market need, the Council will need to pursue strategies that result in the production of quality compost. For instance, the establishment of a source separated kerbside collection service will be required for domestic organic waste.

In addition to ensuring that the raw materials used for the production of compost is free of contaminants, the current Australian Standards for the production of compost, soil conditioners and mulches should also be met (Standards Australia 1997). The standard establishes 'best practice' guidelines for both low and high technology composting systems aimed at achieving the optimum composting conditions. The Australian Standards also defines physical and chemical requirements, quality testing and grading as well as packaging, labelling and marketing requirements. In essence, compliance with the Australian Standard (AS4454) provides for the quality assurance of the product to satisfy market resource security.

On the other hand, when catering for markets that do not require high quality compost, then the Council could safely utilise organic waste sorted from mixed waste to produce compost. Markets that do not require high quality compost include landfill rehabilitation, land reclamation, road construction and urban development.

7.4.1.3 Developing Partnerships and Expertise

The Hobart City Council, with years of experience in waste management including collection technologies and convenient access to public resources, is well placed to take on the role of establishing and operating the composting scheme. On the other hand, the private sector is well equipped in terms of knowledge of commercial production and the development of markets. The private sector also possess an understanding of customer needs and the ability to develop appropriate marketing strategies to create the demand for their product. A partnership between the public and private sector would have several advantages. For instance, the expertise of the public sector in the area of public education and the standard requirements in composting operations, will assist in creating consumer confidence in the quality and safety of the end-product. On the other hand, the private sector's expertise and experience in production could ensure a more lean and cost effective operation.

Community reservation for waste management facilities is a concern that the Hobart City Council will also need to take into consideration. This is crucial as problems such as odours, leachate, machinery noise, dust and spores during turning might be raised by parties who oppose the establishment of large scale composting facilities. It is therefore essential for the Hobart City Council to develop a 'relationship' and incorporate the community as a partner in the recycling scheme. This would mean that the Council would need to ensure that the proposals and the decision making processes involved in establishing such facilities are transparent and participatory. This will ensure for the community to be well informed of the needs and benefits of the recycling scheme. And, by empowering the community through involvement and decision-making, the likelihood of misunderstandings and misinformation about any real or perceived risk can be significantly reduced when the question of siting such facilities arises.

7.5 Incentive Based Programs

Studies carried out in North America show that 20 per cent of households are dedicated composters, 60 per cent can be persuaded to begin composting through proper incentives and 20 per cent will not participate regardless of the incentives offered (Steuteville 1995). The dedicated composters will not need much encouragement to participate in home composting programs. The potential composters, who make up the major proportion of the community, will require some encouragement. Incentives such as discounts on compost bin and municipal rates are potential strategies to motivate households to participate (Johnson 1995; Steuteville 1995).

The survey for this study found that 32 per cent of the households would refuse to pay for a compost bin. Most of these households commented that they were on a low income and that if they were required to compost at home, they should be provided with the compost bin. More than half of the households (55 per cent) were prepared to pay between $10 and $30 for a compost bin, if they were required to take up home composting. However, almost all the households (94.9 per cent) held the opinion that waste disposal is the responsibility of either the Hobart City Council or both the Council and state government. Thus, the majority (73.3 per cent) think that should they be required to compost at home, then compost bins should be subsidised.

Community expectation for subsidised compost bins was also evident in a North American study which found that 75 per cent of households would not have purchased a bin were it not subsidised (Steuteville 1995). It is apparent that subsidy on compost bins is a significant factor in encouraging households to carry out home composting. The survey found that currently one-third of the home composters (31 per cent) use compost bins obtained through the Hobart City Council's bin subsidisation program. This could imply that the subsidy might have acted as an incentive to encourage households to compost at home.

However, the survey also established that only 24.6 per cent of the total home composters (46.7 per cent) have taken up home composting, since the Council began promoting its home composting program. This is a very low participation rate considering that it is 5 years since the Council began promoting its program, and could imply that there is room for improvements. To induce households lacking the motivation to compost at home, an additional stimulus will be required.

The Hobart City Council, in effect need to design incentive programs and pursue proactive strategies that have the capacity to motivate households to take up the practice. One approach would be to charge households the true cost of waste disposal and use incentive based programs to motivate households to take up the practice. For example, households could be charged the waste disposal rate that takes into account the true cost involved in the collection of waste and the management of waste at landfills. An incentive program could then be designed to offer households the option of either paying the full waste disposal rate, or, to reduce their rate by reducing their waste through home composting.

The Hobart City Council also needs to explore the issues associated with carrying out home composting operations and design solutions that would make it convenient for households to take up the practice. For instance, the survey findings establish that of the non-composters (53.5 per cent), the majority (91.5 per cent) are households from medium to high density dwellings, with the obvious space restrictions being the primary reason for the lack in participation. It should also be mentioned that the type of available compost bins is a factor contributing to the non-participation of households from medium to high density dwellings. The type of bin currently promoted in the Hobart City Council's bin distribution program is restrictive in that it needs to be located outdoors and hence is only suited for dwellings with a yard. In this sense the Council's subsidised compost bin strategy does not sufficiently take the needs of households from medium to high density dwellings into account. To deal with the issue of space with regards to the dwellers of medium to high density dwellings, the Council will need to explore the various compost bin types and composting methods. For example, compost bins designed with a base and a lid can be promoted to dwellers of apartments with balconies. A tap placed at the bottom of the unit would allow for any excess fluid to be drained out from this type of unit. The potential of vermicomposting also needs to be examined. Experiences with portable vermicomposting bins have shown them to be highly suitable for use indoors.

7.6 EDUCATIONAL AND PROMOTIONAL PROGRAMS

7.6.1 GENERATING COMMUNITY SUPPORT FOR HOME COMPOSTING PROGRAMS

Currently each council in Tasmania is responsible for the co-ordination, design and the implementation of the home composting program in their municipality. A crucial point in this context is the effectiveness of the Hobart City Councils' promotional and educational programs, in reaching a wide audience and in encouraging households to carry out home composting.

The survey found that the Council's home composting promotional and educational programs suffers from a number of limitations. It appears to have reached just over half the households (58.7 per cent) in the community with two-thirds of these households, indicating dissatisfaction with the levels of information in the educational materials. This point is illustrated through the request from 26 per cent of households who suggested advertising on television as a more accessible medium of information, and, from the majority of the households (60 per cent) for more information on composting techniques. This could explain the poor composting practices of 42.7 per cent of composters, and the composting problems experienced by 46.4 per cent of the composters.

The above mentioned limitations, questions the ability of the Hobart City Council to design, implement and promote an effective home composting program. The Council has only recently extended its services into the area of composting and hence, it is not to be expected to have the necessary expertise to develop and promote the program. The shortcomings of the Hobart City Council's home composting program can be held partly responsible for the low participation rates in the Hobart municipality.

The conclusion is that much can be gained by a comprehensive review of the Council's current educational and promotional programs. A comprehensive education program is crucial for the home composting strategy. The educational materials need to focus on the issues of waste management and the benefits of home composting in waste management, the theory of composting, and, the hands-on approach in setting up and operating a home composting operation. To ensure the best outcome for its home composting program, the Council will need to take a proactive approach in promoting the educational materials. The promotion of home composting should be undertaken through regular workshops, personal home service and demonstration sites.

Demonstration sites are an effective educational tool as they are visual and demonstrate the hands-on aspects of composting. Furthermore, demonstration sites can be specifically designed for different types of waste or households. For instance, demonstration sites strategically located at garden centres can be used to target the home gardeners and inform them on how to compost their garden waste. Demonstration sites in common green areas of medium to high density dwelling zones are especially useful because they are a source of information and have the potential to be used as common composting centres for dwellers of such housing types. Similar demonstration sites could be extended to public areas such as schools and the work environment.

The Council should also examine the potential of establishing a well resourced home composting division within its waste management section. This division should be responsible for research and development of a database on home composting, promotion of a home composting strategy and for training volunteers. The trained members could make personal visits to households to provide hands-on assistance in establishing home composting operations as well as respond to any problems that households may experience with their operations.

An important aspect of the education program should include the issues of safety and hygiene in home composting. The survey found a significant proportion of home composters experience composting problems such as odours, flies, and pests which have the potential to become a public health issue. Due to the nature of composting, it is inevitable that some odours will be generated and flies attracted. Although odours cannot be prevented, they can be minimised through the avoidance of highly odourous materials. These include meat off-cuts, dead pets/animals, disposable nappies and faeces from pets. Covering compost piles (or heaps) with a layer of matured compost will also assist with odour reduction and reduce attraction to flies. Compost bins with a lid and base would greatly assist in controlling vermin, by preventing access to the decomposing materials.

It is also essential that the home produced compost is safe to use for humans, pets and plants. Temperatures in home composting units generally do not rise sufficiently to sanitise the compost (Strauch *et al.* 1995). It can thus be expected that compost produced from home composting operations may be of a poor quality with the potential to carry pathogens and weed seeds. It is therefore essential that education programs focus on these problems and offer appropriate solutions to deal with them. For example, the education materials could emphasise the importance of carrying out the proper techniques in home composting operations and the importance of the stabilisation stage of composting. Home produced compost allowed to stabilise over a period of 6-12 months is generally known to be safe for use. Other measures include preventing pathways for pathogen and weed seeds. Animal faeces and meat off cuts are potential sources for pathogens.

Overall, it can be concluded that for an effective home composting program to be developed and implemented, the expertise of several specialised parties will be required. These should provide expertise in the science of home composting, researching and designing of the informational, educational and promotional programs and promoting the program to a wide audience. It is also apparent that to realise the full benefits of home composting as a waste diversion strategy, a statewide strategy would be required to ensure consistency in both the development and the implementation of the program. The DELM is best placed to coordinate such a strategy, in conjunction with councils and other specialised parties, such as the manufacturers of compost bins.

7.6.2 Generating Community Support for Large Scale Composting

Experiences with large scale composting schemes in the US and the EU indicate that there are a number of problems associated with establishing and operating large scale composting facilities with the main issue being high establishment and operational costs. There is also a perceived risk that contamination with non-compostable and hazardous waste is more likely to occur. A number of strategies have been developed in waste management to minimise the impact of these issues, as previously discussed. Community support and involvement, both in terms of bearing the cost and ensuring the logistic support, is ultimately essential for the successful operation of the recycling scheme.

The survey found that there is strong community support (both financially and logistically) for large scale composting facilities in the Hobart municipality. It is however essential for the Hobart City Council to generate publicity and support for the concept of large scale composting through community education and public participation. Participation of all key sectors of the community, including environmental groups, schools and universities, community groups, specialist organisations and interested individuals should be encouraged. Their involvement in the decision making process from the early stages of the planning process should be facilitated. The Council needs to ensure that the community is fully informed of the benefits of large scale composting for waste management, the real and perceived risk associated with the operations and the high cost associated with establishing and operating such facilities, so that that it can make informed choices. It is more likely for a well informed community to be receptive and supportive to innovative ideas of managing waste. The incorporation of the community in the decision making processes would assist in preventing any possibility of misinterpretation or misunderstanding of the issues, which may otherwise lead to problems such as the NIMBY syndrome.

Direct community participation in the management of the composting facilities should be encouraged. The community should be given the powers to determine how the facilities are managed and operated as well as have the powers to close down facilities that are not operated in accordance with the established requirements. This will assist with establishing confidence in the community for the project.

The economic benefits of accepting large scale composting facilities in their neighbourhood should be promoted. The economic activity generated through the construction of the facilities may support positive economic effects that may entice the community to accept the establishment of the facilities in its neighbourhood.

7.7 STATE GOVERNMENT

The Tasmanian government has not taken sufficient responsibility to ensure that the main aim of the resource recovery strategy (i.e., to reduce the amounts of waste entering landfills) are pursued and achieved. New South Wales and Victoria are currently the only Australian states which have specific waste minimisation legislation in place to deal with waste management issues. New South Wales is also in the process of introducing specific measures to ban green waste from landfill. Tasmania does not have a waste minimisation legislation as such. Waste management, in the state, is regulated through the *EMPCA (1994), LUPAA (1993)* and the TSWMP (1994). However, as long as there is no pressure on councils to actively pursue the objectives established by *EMPCA (1994), LUPAA (1993)* and the TSWMP (1994), there is a danger that the waste disposal authorities will continue with the disposal practices of the past. This concern is justified on the basis that there is relatively cheap land in the state to continue practicing landfilling, and councils have been found to knowingly break their licencing conditions (Bakker pers. comm. 1997; Dettrick pers. comm. 1997). In addition, there is a risk that councils may not be willing to relinquish the monopoly they have over waste management, which accounts for a major part of their budget and workforce. This raises question as to whether councils take responsibility for their actions. Reluctance on the part of the councils to accommodate and adjust to the advances proposed for waste management would severely hamper the path to continued progress of waste management in the state.

The state government's Roles and Reviews Committee recommends the present 60 disposal sites in Tasmania be reduced to 3 centrally located facilities: one for southern Tasmania, one serving the north and a third in the north west (Maunsell 1995). The establishment of regional waste management centres is also recommended in the TSWMP (1994), which proposes that a number of councils should share a common 'state of the art' disposal facility achieving best environmental practices through the economies of scale.

The state government is ideally placed to alleviate the problems discussed above. The arbitrary target of 50 per cent reduction in the amount of waste entering landfills by the year 2000 is one example of how the government can take the lead in ensuring that waste management authorities will be challenged to actively implement their objectives for waste management. The set targets establish focus and encourage improvements. However, in addition to setting goals, the government needs to also initiate directions and to outline solutions. A good example to illustrate this point can be seen in the actions that some US states have taken. Other than simply setting goals for the overall reduction of waste entering landfills, the state of Illinios for example, had gone further by also setting targets for the reduction of organic waste entering landfills and by banning green waste from landfills (Kovacic *et al.* 1992). This resulted in an increase in the number of municipalities taking innovative action to encourage households to compost organics at home and establish large scale composting facilities to deal with organic waste (Kovacic *et al.* 1992). The success of this strategy is evident in a survey carried out by the composting and recycling journal, 'BioCycle', in 1996, which showed that the number of composting sites in the US, had exceeded that of landfills (BioCycle 1996).

The following measures are proposed for the state government to pursue, so as to ensure that councils would take comprehensive action to pursue the strategies of the resource recovery goals and achieve waste reduction in organic waste entering landfills. The state government should: introduce waste minimisation and management legislation that initiate directions and sets guidelines that aim to reduce waste entering landfills; set targets for the reduction of organic waste entering landfills; ban the disposal of green waste in landfills; include waste management as a policy issue in the current political climate of council amalgamation; and through the DELM, establish a state wide home composting strategy.

7.8 CONCLUSION

This study proposed to examine the potential for recycling domestic organic waste in Hobart, within the context of the Tasmanian Solid Waste Management Policy (1994). The Policy (1994) proposed home composting and centralised large scale composting schemes, as the resource recovery strategies to deal with organic waste. The study examined the effectiveness of the Hobart City Council's home composting program as a waste diversion strategy and the viability of the Council to establish and operate a centralised composting scheme, as an alternative to landfilling organic waste.

In theory, the resource recovery strategies could prevent much of the organic waste from entering the waste stream. To determine the effectiveness of the organic waste recovery strategies in practice, the survey was carried out on the households residing in the Hobart municipality. The survey determined the recycling experiences and practices of the community, and the level of community support for establishing large scale composting operations. The survey data were then used to critically analyse the strengths and limitations of the Hobart City Council's home composting strategy and assess the level of community support available for the Council to pursue large scale composting facilities.

The survey found that only a limited proportion of domestic organic waste is currently recycled in the Hobart municipality. The limitations that prevented a more effective diversion of household organic waste from the waste stream, was found to lie, in part, on the Hobart City Council's inability to design and implement effective strategies in its home composting program. The limitations are evident in the: lack of research in designing incentive based program that meets household needs (i.e., current compost bins promoted in the Council's compost bin subsidy program are unsuited for households of medium to high density dwellings); home composting promotional strategies which fail to reach a significant proportion of the community; and the quality of educational programs to provide adequate information on the techniques of home composting and to motivate households to take up the practice.

The study discussed the limitations and proposed a number of educational and promotional strategies, and incentive based programs that would enable the Hobart City Council to increase the effectiveness of its home composting program. This fulfilled the study's aim to assess the effectiveness of the Hobart City Council's home composting program as a waste diversion strategy for domestic organic waste.

The survey assessed the level of support for large scale composting schemes, in the community. There is overwhelming support in the community for the Hobart City Council to operate a centralised large scale composting facility, to deal with the organic fraction of municipal solid waste. The majority of households also matched their support by willing to pay for the recycling scheme and participate in a separate organic waste collection service, to ensure its successful operation.

The study examined the factors that Hobart City Council would need to take into consideration when pursuing large scale composting schemes. The factors discussed include: the types and suitability of both high and low composting technology; ensuring quality control of the finished compost in accordance with the requirements of markets; ensuring the 'best practices' guidelines as set out by Standards Australia are followed in the production of compost; establishing partnership with the private sector for expertise and cost effective operations; and generating public support for the recycling scheme by incorporating the community in the decision making and management processes. This fulfilled the study's aim to assess the viability of the Hobart City Council establishing the recycling scheme.

Further research is however needed before the Hobart City Council could safely embark on establishing a large scale composting scheme for its municipality. It was beyond the scope of this study to determine the financial viability of operating the recycling schemes. Future research would need to investigate the costs and benefits of establishing and operating the recycling scheme. In addition, more research would also be needed to assess the viability of the concept of a single waste management centre, serving all councils in southern Tasmania. This is significant as it has the potential to address issues such as the high cost associated with large scale composting schemes and allow for 'state of the art' facilities to be utilised through the economy of scale. This would assist in improving waste management practices as well as reduce the overall cost of waste management for individual councils.

References

Alexander, M. (1971). Microbial Ecology. New York, John Wiley & Sons, Inc.

Alexander, M. (1977). Introduction To Soil Microbiology. New York, John Wiley & Sons, Inc.

Auditor-General, the (1993). Special Report No.5: Municipal Solid Waste Management. Tasmanian Audit Office, Hobart, Tasmania.

Australian Bureau of Statistics (1991). Census: Characteristics of Tasmania. Australian Bureau of Statistics, Canberra, A.C.T.

Australian Bureau Statistics (1991). Hobart: A Social Atlas. Hobart, Australian Bureau of Statistics, Canberra, A.C.T.

Baeten, D. and Verstraete, W. (1993). In-reactor Anaerobic Digestion of Municipal Solid Waste-Organics. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publication. pp 111-130.

Balmer, C. (1988). Recycling in Tasmania: Current Status and Future Potential. Department of Environment, the Litter Control Council and the Municipal Association of Tasmania, Hobart, Tasmania.

Barlaz, M. A., Ham, R. K. and Schaefer, D. M. (1990). "Methane Production from Municipal Waste: A Review of Enhancement Techniques and Microbial Dynamics." Reprinted from the Critical Reviews in Environmental Controls **19**(6): 557-584.

BioCycle (1996). "Good, Better, Best, Never Let It Rest." BioCycle (April): 4.

Bollen, G. J. (1985). The Fate of Pathogens During Composting of Crop Residues. Composting of Agricultural and Other Wastes Ed. Gasser, K. K. R., London, Elsevier Applied Science Publishers Ltd. pp 282-290.

Brown, K. W. and Donnelly, K. C. (1988). "An Estimation of the Risk Associated with the Organic Constituents of Hazardous and Municipal Waste Landfill Leachates." Hazardous Waste & Hazardous Materials **5**(1): 1-30.

British Medical Assoc. Guide (1989). Infection Control. British Medical Association. Alfred Place, London WC1E 7DP.

Buhr, A. R., McClure, T., Slivka, D. C. and Albrecht, R. (1993). "Market Analysis: Compost Supply and Demand." BioCycle (January): 54-58.

Commonwealth Environment Protection Agency (CEPA) (c1992). National Waste Minimisation and Recycling Strategy. Department of Arts, Sports, the Environment and Territories, Canberra, A.C.T.

Cevallos, A., Gyory, S. and Vigelis, J. (1995). "Camden Composting." Civil Engineering **65**(7): 64-66.

Chen, Y. and Inbar, Y. (1993). Chemical and Stectroscopical Analysis of Organic Pattern Transformation during Composting in Relation to Compost Maturity. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 551-600.

Clouser, D. L. (1989). Resource Recovery Of Solid Waste Using Source Separation Recycling - Case Study, Glenorchy, Tasmania. University of Tasmania, Hobart, Tasmania.

Cringer, G. K., Kezis, A. S. and Oconnor, J. P. (1995). "Regional Composting Of Waste Paper And Food." BioCycle **36**(1 January): 66-67.

Daniel, D. E. (1995). Clay Liners. Geotechnical Practice for Waste Disposal. Ed. Daniel, D. E., London, Chapman & Hall. 137-163.

Davis, B.W., (1985). Federalism and Environmental Politics: An Australian Overview". The Environmentalist **5**(3): 269-278.

de Bertoldi, M., Vallini, G. and Pera, A. (1985). Technological Aspects of Composting Including Modelling and Microbiology. Composting of Agricultural and Other Wastes Ed. Gasser, J. K. R., London, Elsevier Applied Science Publishers Ltd. pp 27-41.

de Bertoldi, M. and Zucconi, F. (1987). Composting of Organic Residues. Bioenvironmental System Vol. 111 Ed. Wise, D. L., Boca Raton, Florida, CRC Press Inc. pp 95-136.

de Vaus, D. A. (1991). Surveys in Social Research. London, Allen & Unwin Pty Ltd.

Department of Environment & Planning (DEP) (1992). Tasmanian Solid Waste Management Policy (Position Paper). Division of Environmental Management/Tasmanian Recycling and Litter Awareness Council, Hobart, Tasmania.

Department of Environment and Land Management (DELM) (1993). Tasmanian Solid Waste Management Survey. Division of Environmental Management, Hobart, Tasmania.

Department of Environment and Land Management (DELM) (1994a). An Information Guide to the Land Use Planning and Approvals Systems in Tasmania. Planning Division, Department of Environment and Land Management, Hobart, Tasmania.

Department of Environment and Land Management (DELM) (1994b). Tasmanian Solid Waste Management Policy. Division of Environmental Management, Hobart, Tasmania.

Doedens, H. and Theilen, U. (1992). Effluent Requirements and Related Leachate Treatment Processes. Landfilling of Waste: Leachate Eds. Christensen, T. H., Cossu, R. and Stegmann, R., London, Elsevier Science Publishers Ltd.

Dowson, G. (1991). Domestic Waste Composition Study. Tasmanian Recycling and Litter Awareness Council, Hobart, Tasmania.

Dunson, J. P. E. (1993). Control of Odours by Physical-Chemical Approaches. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 242-261.

EMPCA (1994). Environmental Management and Pollution Control Act (1994). Tasmanian Government Legislation, Tasmanian Government, Tasmania.

Evans, G. D. (1994). "Forum: A Rationale for Recycling." Environmental Management **18**(3): 321-329.

Fagg, R. (1992). Newsprint Recycling. Recycling in The 1990s: Towards Total Waste Management. Sydney, N.S.W, Environment Protection Agency and Local Government & Shire Assocation of New South Wales.

Farrell, J. B. (1993). Fecal Pathogen Control During Composting. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 282-300.

Finnveden, G. (1992). Landfilling - a forgotten part of Life Cycle Assessments. Product Life Cycle Assessment - Principles and Methodology - Nord 1992:9 Ed. The Nordic Council. AKA- PRINT AS Arhus 1992.

Fowler, J. F. J. (1984). Survey Research Methods. Beverly Hills, USA, Sage Publications Inc.

Fowler, H. W. and Fowler, F. G. (1974). Concise Oxford Dictionary of Current English. Ely House, London, Oxford University Press.

Fricke, K. and Vogtmann, H. (1993). "Quality of Source Separated Compost." BioCycle **34**(October 93): 64.

Gardner, G. (1976). Social Surveys for Social Planners. Artarmon, N.S.W., Holt, Rinehart and Winston Pty Ltd.

Glauser, M., Aragno, M. and Gandolla, M. (1978). Anaerobic Digestion of Urban Waste: Sewage Sludge and Organic Fraction of Garbage. Bioenvironmental System Vol. 111. Ed. Wise, D. L., Boca Raton, Florida, CRC Press Inc.

Glover, M., Ed. (1995). From Waste Management to Resource Recovery: The Integrated Approach. Solid Waste Infrastructure Development Handbook. Grocery Manufacturers of Australia SWID Group.

Gotaas, H. B. (1956). Composting: Sanitary Disposal and Reclamation of Organic Waste. Geneva, World Health Organization.

Gouin, F. R. (1991). "The need For Compost Quality Standards." BioCycle **32**(August): 44.

Haas, C. N., Rose, J. B., Gerba, C., and Regli, S. (1993). "Risk Assessment of Virus in Drinking Water." Society for Risk Analysis. **13**(5): 545-552.

Halstead, J. M. and Whitcomb, J. L. (1994). "Strategies for Municipal Solid Waste Composting Facility Siting." BioCycle **35**(11, November): 39-42.

Hamelers, H. V. M. (1993). A Theoretical Model of Composting Kinetics. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 36-58.

Handreck, K. (1992). The Composting of Municipal Solid Waste. CSIRO Division of Soils, South Australia.

Haynes, M. (1996). An Outline of Tasmania's Resource Management and Planning System. Office of the Minister for Environment and Land Management, Hobart, Tasmania.

Hoitink, H. A. J. and Keener, H. M. (1995). "Composting Organics in the Netherlands." BioCycle **36**(1, January): 37-38.

Hubick, K.T. (1991). Management and Technologies of Waste. Department of Industries, Technology and Commerce. Canberra, A.C.T., CPN Publications.

Hughes, E. G. (1980). The Composting of Municipal Wastes. Handbook of Organic Waste Conversion Ed. Bewick, M. W. M., New York, Van Nostrand Reinhold Company. pp 108-134.

Jager, E., Ruden, H. and Zeschmarlahl, B. (1994). "Composting Facilities 2 Communication -Airbourne Micro-organisms at Different Working Places at Composting Facilities." Zentralblatt fur Hygiene und Umweltmedizin **196** (4 December 94): 367-379.

Johnson, H. J. (1995). "Backyard Composting Education Programs." BioCycle **36**(1 January): 75-77.

Keener, H. M., Marugg, C., Hansen, R. C. and Hoitink, H. A. J. (1993). Optimizing the Efficiency of the Composting Process. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 59-94.

Kirchmann, H. and Widen, P. (1994). "Separately Collected Organic Household Waste - Chemical Composition and Composting Characteristics." Swedish Journal of Agricultural Research **24**(1): 3-12.

Kovacic, D. A., Cahill, R. A. and Bicki, T. J. (1992). "Compost - Brown Gold or Toxic Trouble." Environ. Sci. Technol. **26**(1): 38-41.

LaGasse, R. C. (1992). "Marketing Organic Soil Products." BioCycle **33**(March): 30-33.

Lake, I. R., Bateman, I. J. and Parfitt, J. P. (1996). "Assessing a Kerbside Recycling Scheme And Willingness to Pay Case Study." Journal of Environmental Management **46**: 239-254.

Leonard, J. J. (1993). Management of Wastes form Tasmanian Bioresource Industries. Environmental Management Division, Department of Environment & Land Management, Hobart, Tasmania.

LUPAA (1993). Land Use Planning and Approval Act (1993). Tasmanian Government Legislation, Tasmanian Government, Tasmania.

Marchand, G., Lavoie, J. and Lazure, L. (1995). "Evaluation of Bioaerosols in a Municipal Solid Waste Recycling and Composting Plant." Journal of the Air & Waste Management Association **45**(October): 778-781.

Mathur, S. P. (1991). Composting Processes. Bioconversion of Organic Waste Materials to Industrial Products Ed. Martin, A. M., London, Elsevier Applied Science Ltd. pp 148-180.

Maunsell Pty. Ltd. (1995). Southern Tasmanian Solid Waste Management Study, Final Report, Document No. CSB:43295:313.c13. Government of Tasmania, Hobart.

Miller, F. C. (1991). Biodegradation of Solid Wastes by Composting. Biological Degradation of Waste Ed. Martin, A. M., Essex, Elsevier Science Publishers Ltd. pp 1-30.

Miller, F. C. (1993). Minimizing Odor Generation. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 219-241.

Millner, P. (1995). "Bioaerosol and Composting." BioCycle **36**(1 January): 48-54.

Mitchell, R. C. and Carson, R. T. (1989). Using Surveys to Value Public Goods: The Contingent Valuation Method. New York, Resources for the Future.

Morel, J. L., Colin, F., Germon, J. C., Godin, P. and Juste, C. (1985). Methods for the Evaluation of the Maturity of Municipal Refuse Compost. Composting of Agricultural and Other Wastes Ed. Gasser, J. K. R., London, Elsevier Applied Science Publishers. pp 56-72.

Moser, C. S. and Kalton, G. (1972). Survey Methods in Social Investigation. New York, Basic Books, Inc.

National Center for Resource Recovery, Ed. (1974). Sanitary Landfills: A State Of The Art Study/National Center for Resource Recovery. Lexington, Mass., Lexington Books.

Nordstedt, R. A., Barkdoll, A. W. and Schroeder, R. M. (1993). Composting of Yard Wastes. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 154-167.

Pearce, D., Markandya, A. and Barbier, E. B. (1989). Blueprint For A Green Economy. London, Earthscan Publication Limited.

Plotkin, S. and Ram, N. M. (1984). Multiple Bioassays to Assess the Toxicity of Sanitary Landfill Leachate. Landfill Leachate. Eds. Senior, E. and Shibani, S. B., Boca Raton, Florida, CRC Press, Inc.

Poulsen, O. M., Bream, N. O., Ebbehoj, N., Hansen, A. M., Ivens, U. I., Lelieveld, D. V., Malmros, P., Matthiasen, L., Neilsen, B. H., Neilson, E. M., Schibye, B., Skov, T., Stenbaek, E. I. and Wilkins, K. C. (1995). "Sorting and Recycling Domestic Waste - Review of Occupational Health Problems and their Possible causes." Science and the Total Environment **168**(May 19): 33-56.

Prince, A. (1997). "Microbial Approach to Recycled Organics." Waste Management and Environment (April): 22,30.

Rajan, M. R., Balasubramanian, S. and Raj, S. P. (1994). "Accumulation of Heavy Metals in Sewage-Grown Fishes." Bioresource Technology **52**: 41-43.

Rathje, W. L. (1989). "Rubbish." The Atlantic Monthly (December): 99-108.

Rathje, W. L. (1991). "Once and Future Landfills." National Geographic May: 116-134.

Reschovsky, J. D. and Stone, S. E. (1994). "Market Incentives to Encourage Household Waste Recycling: Paying for What You Throw Away." Journal of Policy Analysis and Management **13**(1): 120-139.

Rugge, K., Bjerg, P. L. and Christensen, T. H. (1995). "Distribution of Organic Compounds from Municipal Solid Waste in the Groundwater Downgradient of a Landfill." Environmental Science & Technology **29**(5): 1395-1400.

Senior, E. and Shibani, S. B. (1990). Landfill leachate. Microbiology of Landfill Sites Ed. Senior, E., Boca Raton, Florida, CRC Press Inc. pp 82-105.

Snelson, J. (1992). North American Waste Management Strategies: Seattle's Road To Recovery. Recycling In The 1990s: Towards Total Waste Management. Sydney, N.S.W., Environment Protection Agency and Local Government & Shire Association of NSW.

Sobsey, M. D. (1978). "Field Survey of Enteric Viruses In Solid Waste Landfill Leachate." Am. Journal of Public Health **68**(9): 858-864.

Society of Environmental Toxicology and Chemistry (1991). A Technical Framework for Life Cycle Studies. Pensacola, FL 32501-3307, USA, Society of Environmental Toxicology and Chemistry (SETAC) & SETAC Foundation for Environmental Education.

Standards Australia (1997). Australian Standards for Compost, Soil Conditioner and Mulch, AS4454. Standards Australia, Canberra, A.C.T.

Stentiford, E. I. (1993). Diversity of Composting Systems. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications. pp 95-110.

Steuteville, R. (1995). "Measuring Diversion Through Home Composting." BioCycle **36**(3, March): 74-76.

Strauch, D., Gieb, S. and Philipp, W. (1995). "Hygienic Aspects of Small Scale Composting." Hygiene Medizin **20**(3): 117-131.

United States Environmental Protection Agency (US EPA) (1990). Characterization of Municipal Solid Waste in the United States: 1990 Update. (US) Environmental Protection Agency, Washington, DC. USA

United States Environmental Protection Agency (US EPA) (1993). Draft Strategy on Hazardous Waste Minimisation and Combustion: Waste Minimisation National Plan. (US) Environmental Protection Agency, Washington, DC. USA

Van Der Hoek, K. W. and Oosthoek, J. (1985). Composting Odour Emission and Odour Control by Filtration. Composting of Agricultural and Other Wastes Ed. Gasser, J. K. R., London, Elsevier Applied Science Publishers. pp 257-270.

Walker, K. J. (1992). The Politics of Environmental Policy. Australian Environmental Policy Ed. Walker, K. J., Kensington, NSW, University Press Ltd.

Warmer Factsheet (1991). Compost. Warmer Bulletin. Turnbridge Wells, Kent TN4 8BS, UK.

Waste Management Association of Australia (WMAA) (1994). Landfill Gas: Tapping into member know how. WMAA News. Cover page. Sydney, N.S.W.

William, T. O. and Miller, F. C. (1993). Composting Facility Odor Control Using Biofilters. Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects Eds. Hoitink, H. A. J. and Keener, H. M., Worthington, Ohio, Renaissance Publications, pp 263-281.

Personal Communication

Bakker, M. (1997). Environmental Officer. Waste Management and Community Section. Environmental and Planning Division. Department of Environment and Land Management. Hobart, Tasmania.

Chew Liew (1996). Director of Environmental Management. Hobart City Council. Hobart, Tasmania.

Clarke, J. (1997). Solid Waste Co-ordinator. Hobart City Council. Hobart, Tasmania.

Dare, R. (1996). Resource Co-operative. Hobart, Tasmania.

Dettrick, D. (1997). Environmental Officer. Waste Management and Community Section. Environmental and Planning Division. Department of Environment and Land Management. Hobart, Tasmania.

Kriwoken. L (1997) Lecturer. Centre for Environmental Studies. Department of Geography and Environmental Studies. University of Tasmania. Hobart, Tasmania.

Mitchell, D. (1996). Waste Management. Brighton City Council. Brighton, Tasmania.

Wilde, P. (1997) Lecturer (retired). Department of Geography and Environmental Studies. University of Tasmania. Hobart, Tasmania.

APPENDICES

Appendix 1: Some pathogens known to be found in organic waste which are harmful to humans and animals

Bacteria	Enterobacteria	Viruses	Parasites	Fungi
Salmonella	Proteus	Enterovirus	Taenia Eggs	*Aspergillus fumigatus* and moulds
E. Coli	Pseudomonas	Hepatitis A Virus	Roundworm Eggs	
Yorsinia	Klebsiella	Poliomyelitis Virus	Ascaris Eggs	
Streptococcus	Serratia	Coxsackle Viren		
Mycobacterium tuberculosis	Citrobacteria	Echo Virus		
		Reovirus		
		Adeno Virus		
		Parvovirus		
		Ascaris lumbricoides		

(Source: Strauch *et al* 1995; Hughes 1980; Gotaas 1956)

Appendix 2: Some pathogens known to be found in organic waste that are harmful to plants

Nematodes	Viruses	Bacteria	Fungi
Globodera rostochiensis	Tobacco rattle virus	*Erwinia carotovora var. chrysanthemi*	*Olpidium brassicae*
Meloidogyne hapla and *M. incognita* (commonly known as two root-knot nematode)	Tulip breaking virus	*E. amylovora*	*Fusarium oxysporum*
	Tobacco necrosis virus	*Pseudomonas phaseolicola*	
	Tobacco mosaic virus		

(Source: Bollen 1993)

Appendix 3: Time taken for the destruction of some common pathogen

Ascaris lumbricoides eggs	Killed in less than an hour at 50°C
Brucella abortus	Killed within 1 hour at 55°C or within 3 minutes at 62-63°C
E. amylovora	Killed at temperatures above 40°C
Entamoeba histolytica cysts	Killed within a few minutes at 45°C and a few seconds at 55°C
Erwinia chrysanthemi	Killed in 1 week when exposed to temperatures of 40°C
Escherichia coli	Most killed within 1 hour at 55°C and within 15-20 minutes at 60°C
Fusarium oxysporum	Killed at 55-67°C
Globodera rostochiensis, Meloidogyne hapla and *M. incognita*	Killed within 4 hours at 45°C or 1 hour at 50°C
Olpidium brassicae	Killed at 56-67°C
polio virus	Killed within 30 minutes at 54°C
Pseudomonas phaseolicola	Killed at temperatures below 35°C
Salmonella sp	Killed within 1 hour at 55°C and 15-20 minutes at 60°C
Salmonella typhosa	No growth beyond 46°C; killed within 30 minutes at 55°-60°C or 20 minutes at 60°C
Shigella sp	Killed within 1 hour at 55°C
Streptococcus pyogenes	Killed within 10 minutes at 54°C
Taenia saginata	Killed within a few minutes at 55°C
Tobacco rattle virus	Inactivated at 60°C
Trichinella spiralis larvae	Killed at 55°C and instantly killed at 60°C

(Source: Bollen 1985; Hughes 1980; Gotaas 1956)

Appendix 4: Performance targets for recycling in Tasmania

Materials	Amount Collected in 1993		Interim Target for 1995
	Tonnes	per cent	per cent
Aluminum	927	30	65
Glass (Cullet)	14,800	38	45
Plastic PET (No 1)	700	15	30
Plastic HDPE (No 2)	2,000	1	50
Plastic PVC (No 3)	900	<1	45
Liquid Paperboard	1,100	3	20
Newspaper	12,000	8	40
Office Paper/Cardboard	35,000	30	50
Lubricating Oil (ml)	20	35	60
Tyres	45,000	?	50
Batteries (Vehicle)	50	50	80
Batteries (Hg/Cd)	?	?	60
Ferrous Metal	14,000	70	90
Putrescibles (Domestic)	35,000	?	45
Building Materials	?	?	45

(Source: DELM 1994b)

Appendix 5: Dwelling types in the sample area

Collection Districts(CD)	Medium to High Density Housing				Separate House	
Suburb	C/Terr*	Flats	Total	%	Houses	%
Mt. Nelson						
050903	39	36	75	24	235	76
050901	5	58	63	21	238	79
Total	44	94	138	22.6	473	77.4
Lenah Valley						
050304	15	16	31	15	177	85
050312	4	34	38	22	132	78
Total	19	50	69	18.3	309	81.7
New Town						
050101		99	99	37.1	168	62.9
050102	4	127	131	51	125	49
Total	4	226	230	44.0	293	56.0
Total All CD	67	370	437	28.9	1,075	71.1
*Con-join or terrace dwellings						

Appendix 6: Dwelling types in the suburbs in which the sample areas are located

Selected Suburbs	Medium to High Density		Separate Houses	
	Total	%	Total	%
Mt. Nelson	317	29.8	747	70.2
Lenah Valley	275	18.4	1,217	81.6
New Town	1,178	33.6	2,321	66.3
Total	1,770	29.2	4,285	70.8

Appendix 7: Data on dwelling types of all suburbs in the Hobart Municipality

	Medium to High Density Housing				Separate Houses	
Suburbs	C/Terr	Flats	Total	%	Houses	%
Hobart	72	85	157	58.8	110	41.1
Lenah Valley	113	162	275	18.4	1,217	81.5
Mt. Nelson	150	167	317	29.7	747	70.2
Mt. Stuart	72	248	320	26.6	880	73.3
New Town	254	924	1,178	33.6	2,321	66.3
North Hobart	243	200	443	42.2	605	57.7
South Hobart	204	647	851	35.0	1,579	64.9
West Hobart	291	708	999	34.6	1,884	65.3
Sandy Bay	327	1,188	1,515	32.4	3,147	67.5
Total Dwelling	1,726	4,329	6,055	32.2	12,490	67.3
*Con-join or terrace dwellings						

Appendix 8: Comparison of socio-economic status between sample areas

Collection District	Socio-Economic Status (Total Annual Income)					
	Less than $25,000		$25,000 to $50,000		More Than $50,000	
Mount Nelson	Total	%	Total	%	Total	%
050901	39	25.8	56	37.1	56	37.1
050903	32	17.9	60	33.5	87	48.6
Lenah Valley						
050304	27	21.4	57	45.2	42	33.3
050312	23	22.8	45	44.6	33	32.7
New Town						
050101	58	49.2	49	41.5	11	9.3
050102	45	42.9	39	37.1	21	20.0
Total	224	28.7	306	39.2	250	32.0

Appendix 9: Comparison of socio-economic status between selected suburbs in which sample areas are located

Suburbs	Less than $25,000		$25,000 to $50,000		More than $50,000	
	Total	%	Total	%	Total	%
Mt. Nelson	188	27.8	249	36.8	239	35.4
Lenah Valley	268	26.7	459	45.7	278	27.7
New Town	673	36.4	725	39.3	449	24.3
Total	1129	32.0	1433	40.6	966	27.4

Appendix 10: Comparison of socio-economic status of all suburbs in the Hobart Municipality

Hobart LGA	Less than $25,000		$25,000 to $50,000		More than $50,000	
Suburbs	Total	%	Total	%	Total	%
Hobart	47	36.2	50	38.5	33	25.4
Lenah Valley	268	26.7	459	45.7	278	27.7
Mt. Nelson	188	27.8	249	36.8	239	35.4
Mt. Stuart	213	29.1	295	40.4	223	30.5
New Town	673	36.4	725	39.3	449	24.3
North Hobart	203	40.7	183	36.7	113	22.6
Sandy Bay	599	24.2	822	33.2	1,057	42.7
South Hobart	424	34.5	456	37.1	349	28.4
West Hobart	471	33.2	511	36.0	436	30.7
Total	3,086	32.1	3,750	39.0	2,777	28.9

Appendix 11: A copy of the questionnaire used for the public survey

University of Tasmania
Centre for Environmental Studies
Survey on the Recycling of Organic Waste

Part 1 General Information

Questionnaire No: ____________ *QuNo* ☐

Suburb ________________ *Suburb* ☐

Address ______________ *Add* ☐

Housing Type:

1. Upper floor Flat (__)
2. Ground floor Flat (__)
3. Unit (__)
4. Conjoined or Terrace (__)
5. House with yard (__) *Dwell* ☐

Part 2 Current Recycling Program

(2.1) Do you participate in the present household recycling program offered by your municipality?

(1) YES (__) (2) NO (__) *PresRec* ☐

(2.2) Some people think that separating recyclable items in a separate bin is an inconvenience. Would you:

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
(_1_)	(_2_)	(_3_)	(_4_)	(_5_)

Incon ☐

Part 3 Disposal of Organic Waste

(3.1) How do you dispose of: **(Use Visual Display)**

(3.1.1) Food Waste:

1.	Vegetable scraps	(__)	*DispVeg*	☐
2.	Meat scraps and Bone	(__)	*DispMeat*	☐
3.	Left over Food Scraps	(__)	*DispLeft*	☐
4.	Egg Shells	(__)	*DispEggSh*	☐
5.	Tea Leaves and Coffee grains	(__)*DispOthFood* ☐		

(3.1.2) Garden Waste ** If No Garden (__) *NoGdn* ☐

1.	Garden Weeds	(__)	*DispWeeds*	☐
2.	Lawn Clippings	(__)	*DispLawn*	☐
3.	Raked Leaves	(__)	*DispLeaves*	☐
4.	Bush and Branch trimmings	(__)	*DispBshBrn*	☐
5.	General Garden Waste	(__)	*DispOthGdn*	☐

(3.1.3) Paper Waste

(a)	Newspaper	(__)	*DispNewsp*	☐
(b)	White Paper	(__)	*DispWhiteP*	☐
(c)	Paper Packaging/Cardboard	(__)	*DispPackP*	☐
(d)	Magazines	(__)	*DispMagP*	☐
(e)	Other ____________________	(__)	*DispOthP*	☐

Part 4 Awareness of Home Composting Strategies

Composting of suitable organic waste at home is being promoted as a means to reduce waste by the Tasmanian Solid Waste Management Policy (Use Visual Display)

(4.1) From the list below please identify:

(A) the promotional programs through which you have received information about home composting programs.

(B) rank in order the source of information you found to be most helpful (i.e. 1, 2, 3 - 10, with "1" being the most effective and"10" being the least effective).

Programs	**A**	**B**				
1. Brochures	(__)	(__)	*BrochA*	☐	*BrochH.*	☐
2. Educational Workshops	(__)	(__)	*WkshpA*	☐	*WkshpH*	☐
3. Demonstration Sites	(__)	(__)	*DemoA*	☐	*DemoH*	☐
4. School Programs	(__)	(__)	*SchProgA*	☐	*SchProgH*	☐
5. Portable Displays	(__)	(__)	*PortDisA*	☐	*PortDisp*	☐
6. Bin Distribution	(__)	(__)	*BinDistA*	☐	*BinDistH*	☐
7. Utility Rates Insert	(__)	(__)	*UtilRtInA*	☐	*UtilRtIns*	☐
8. Newspaper Ads	(__)	(__)	*NewAdA*	☐	*NewAdA*	☐
9. Books or Booklets	(__)	(__)	*Book/letA*	☐	*Book/letH*	☐
10. Word of Mouth	(__)	(__)	*WdOfMth*	☐	*WdOfMtH*	☐
11. Other: ________	(__)	(__)	*OthA*	☐	*OthH*	☐
12. None	(__)	(__)	*NonA*	☐	*NonH*	☐

(4.2) Is the information on "how to compost at home" adequate in the promotion programs that you are aware off?

(1). YES (__) (2) NO (__) (3) N/A (__) *InfoAd* ☐

(4.3) How do you think the home composting programs could be improved?

____
____
____

Part 5 Incentives for Home Composting

(5.1) If you were required by your council to use a compost bin, how much would you be willing to pay for a suitable bin?

(1) Nothing (__)
(2) less than 10 dollars (__)
(3) between 10 - 20 dollars (__)
(4) between 20 - 30 dollars (__)
(5) between 30 - 40 dollars (__)
(6) more than 40 dollars (__) *PayFBin* ☐

(5.2) Some people think that the cost of compost bins should be subsidised?

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
(_1_)	(_2_)	(_3_)	(_4_)	(_5_)

Com/B/Su ☐

(5.3) If Strongly Agree/ Agree / Undecided, who should subsidise it?

(1) Councils (__) (2) State Gov (__) (3) Both (__) *W/Sub* ☐

(5.4) If Undecided/ Disagree/ Strongly Disagree, why should it not be subsidised?

____
____
____

Part 6 Home Composting

(6.1) Do you compost organic matter at home?

1. YES (__) 2. NO (__)***If NO please go to part 7** *HomeComp* ☐

If YES how long have you been composting for?

____ *lngth* ☐

(6.2) Do you compost in:

1. a bin purchased from/through your council (__)
2. a bin purchased from other sources (i.e. hardware shop) (__)
3. a home made device (__)
4. Other (__)

Please specify other ______________________________ *CompType* ☐

(6.3) Please indicate number of compost bins/heap.

Compost Bin _______________

Compost heap _______________ *NoOfBn* ☐

(6.4) How often do you turn (aerate) the compost?

At least:

(1) Once a week (__) (4) Other __________ (__)

(2) Once a month (__) (5) Never (__)

(3) Once in 3 months (__) *HwOftT* ☐

(6.5) By how much do you think home composting has reduced your weekly garbage?

(1) 0 to 25% (__) (2) 25 to 50% (__)

(3) 50 to 75% (__) (4) 75 to 100% (__) *%R* ☐

(6.6) What do you do with the finished compost?

(1) Garden (__) *Gdn* ☐

(2) Lawn (__) *Lwn* ☐

(3) Potting Mix (__) *P'Mx* ☐

(4) Give Away (__) *G'away* ☐

(5) Other (__) *Oth* ☐

(6.7) Does you compost smell or attract pest such as flies, rats, possums, etc?

(1) YES (__) (2) NO (__) *Comlss* ☐

(6.8) If YES please indicate issue/s:

(1)	Odours	(__)	*Odr* ☐
(2)	Possums	(__)	*P'sm* ☐
(3)	Rats	(__)	*Rts* ☐
(4)	Flies	(__)	*Fli* ☐
(5)	Other	(__)	*Oth* ☐

Please specify Other ________________

(6.9) Do you regard the issue/s as a problem.

(1) YES (__) (2) NO (__) *Prob* ☐

Part 7 To Identify the Levels of Community Support for Large Scale Recycling (Composting) of Organic Waste

(7.1) Presently some councils offer mulching services at their tips for garden waste. Have you used such a service?

(1) YES (__) (2) NO (__) (3) N/A (__) *MulSc* ☐

(7.2) If a separate collection was made for garden waste would you use such a service?

(1) YES (__) (2) NO (__) (3) N/A (__) *GdnWCol* ☐

(7.3) In many parts of the Western world, organic waste is collected, composted and sold. Do you think it is a good idea for your council to collect organic waste and then compost and sell it?

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	
(_1_)	(_2_)	(_3_)	(_4_)	(_5_)	*GoodIdea* ☐

(7.4) Would you participate in the separate household organic waste collection service, by separating organic waste into a separate bin?

(1) YES (__) (2) NO(__)* *ParOWC* ☐

*** If NO please indicate why from list below.**

1.Choose not to participate (__)
2. Compost the organics at home (__)
3. Other ____________________ (__) *NoPar* ☐

(7.5) If a special rate is introduced to cover the cost involved in recycling (composting) organic waste, would you be willing to contribute financially, to ensure the success of the recycling scheme?

(1) YES (__) *(2) NO (__) #(3) Don' Know (__) *SpecRt* ☐

*** If YES please indicate amount from list below.**

(1) 0 to $5 p/year (__) (4) 15 to $20 p/year (__)

(2) $5 to $10 p/year (__) (4) N/A (__)

(3) 10 to $15 p/year (__) *SpecAm* ☐

 # If NO please indicate reasons why.

____
____
____

Part 8 Personal

(8.1) Home tenure

(1) Own home (__) (3) Public Rental (__)

(2) Private Rental (__) *HmTen* ☐

(8.2) Highest level of education. **(Use Visual Display)**

Status	Education	Number		
1. Primary	(__)	(__)	*PriE* ☐	*PriN* ☐
2. Secondary	(__)	(__)	*SecE* ☐	*SecN* ☐
3. TAFE	(__)	(__)	*TAFEE* ☐	*TAFEN* ☐
4. College/University	(__)	(__)	*C/Uni* ☐	*C/UniN* ☐

(8.3) Occupation of people living in the household. **(Use Visual Display)**

Status	Occupation	Number	
1. Homemaker	(__)	(__)	*HmMkN* ☐
2. Retired	(__)	(__)	*RetN* ☐
3. Unemployed	(__)	(__)	*UnempN* ☐
4. Student	(__)	(__)	*StudN* ☐
Paid Employment			
5. Managerial and administ	(__)	(__)	
6. Professionals	(__)	(__)	
7. Para-prof and Technical	(__)	(__)	*ManToProfTechN* ☐
8. Clerical	(__)	(__)	
9. Sales and personal service	(__)	(__)	*ClToSalPerN* ☐
10. Tradesperson	(__)	(__)	
11. Plant and machine operator	(__)	(__)	
12. Labourers	(__)	(__)	*TradsToLabN* ☐

(8.4) Household type (Based on usual residents) **(Use Visual Display)**

Household Type	Age of Head	Age of Children	People in Household	
Young Couple	<35	No Children	2	1
Young Family	18-35	<6 yrs	2+	2
Sch Age Family	25-55	6-17	2+	3
Older Family	35-65	18+	2+	4
Mid-Aged Couple	36-65	No Children	2	5
Older Couple	<65	No Children	2	6
Single Person	<65	No Children	1	7
Single Person	>65	No Children	1	8
Singles Sharing	Any	No Children	2+	9
Other				10

? Too many Variables

Appendix 12

Introduction Statement

Good morning/afternoon Sir/Madam

My name is Paul Jay and am undertaking a Masters in Environmental Studies at the Centre of Environmental studies, University of Tasmania. I am undertaking a survey to examine the potential for recycling organic waste in Tasmania. The survey aims to examine the level of support in the community for organic waste recycling.

Currently, almost 70% of urban solid waste is organic in nature and can be recycled to compost. However, presently the organics are mostly buried in landfills. This survey aims to identify if:

- home composting is a viable means to recycle organic waste;
- Councils should operate centralised large-scale composting facilities to recycle organic waste; and
- there is community support for a source separated organic waste collection service which entails the use of a separate bin for left over food waste and paper waste, and a garden waste collection service for garden waste.

Concluding Statement

Your contribution to this survey is appreciated. If you want the results of this survey mailed to you, please let me know and I would be pleased to forward them to you. Thank you for your assistance.

Appendix 13: A copy of the Visual Aid used in the survey

For Part 3	List of Disposal Methods
Discard In Garbage Service	(_1_)
Take to the Tip	(_2_)
Kerbside Recycling Bin	(_3_)
Take to a Recycling Depot	(_4_)
Burn (i.e. fire place, incinerator etc.)	(_5_)
Bury	(_6_)
Compost at Home	(_7_)
Other	(_8_)

For Part 4	Home Composting Programs		
1	Brochures	7	Utility Rates Insert
2	Educational Workshops	8	Newspaper Ads
3	Demonstration Sites	9	Books or Booklets
4	School Programs	10	Word of Mouth
5	Portable Displays	11	Others
6	Bin Distribution		

For Part 8.2 Education			
1	Primary	2	Secondary
3	TAFE	4	College/University

continued next page

For Part 8.3 Occupation

1	Homemaker	7	Para-Professional/Technical
2	Retired	8	Clerical
3	Unemployed	9	Sales & Personal Service
4	Student	10	Tradesperson
5	Managerial/Administration	11	Plant/Machine Operator
6	Professionals	12	Labourers

For Part 8.4 Household Type

Household Type	Age of Head	Age of Children	People in Household
Young Couple	<35	No Children	2
Young Family	18-35	Less Than 6 yr.	2+
School-Age Family	25-55	6-17	2+
Older Family	35-65	18+	2+
Mid-Aged Couple	36-65	No Children	2
Older Couple	<65	No Children	2
Single Person	<65	No Children	1
Single Person	>65	No Children	1
Singles Sharing	Any	No Children	2+
Other			